J. J. Madden 724

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Department of Physics and Astronomy
THE UNIVERSITY OF IOWA
Iowa City, Iowa

FINAL REPORT

IMP-D and IMP-E

Explorer 33 and Explorer 35

9076

Contract NAS5-9076

between the

Goddard Space Flight Center
of the National Aeronautics and Space Administration

and

Department of Physics and
Astronomy, University of Iowa

January 1970

THE UNIVERSITY OF IOWA
IOWA CITY, IOWA 52240

Department of Physics and Astronomy
Area 319: 353-4343

FOREWORD

This final report on contract NAS5-9076 comprises a bibliography of publications as of January 1970 and a compilation of abstracts or first pages of each item in the bibliography. A full copy of any paper is available on request.

Despite the termination of GSFC/NASA contract NAS5-9076, our work on the data of IMP-D and IMP-E remains at a vigorous level and will continue for several years. The most comprehensive and substantial studies will appear at later dates.

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Explorers 33 and 35

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JOURNAL OF GEOPHYSICAL RESEARCH VOL. 72, NO. 3 FEBRUARY 1, 1967

Observed Particle Effects of an Interplanetary Shock Wave on July 8, 1966

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At 2106 UT on July 8, 1966, a distinctive, discontinuous drop in the intensities of solar protons $E_p \sim 0.5$ Mev was observed by Explorer 33 in interplanetary space at 187,000 km in the antisolar direction from the earth. The protons had been emitted by the sun in a flare whose onset time was 0027 UT on July 7. The intensity drop is attributed to the effects of an interplanetary shock wave whose detailed structure was observed by a triaxial flux gate magnetometer on the same satellite.

JOURNAL OF GEOPHYSICAL RESEARCH VOL. 72, NO. 23 DECEMBER 1, 1967

The Solar X-Ray Flare of July 7, 1966

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By means of a mica window Geiger-Mueller tube on earth satellite Explorer 33, a major solar X-ray flare was observed with 81.8-sec time resolution on July 7, 1966. The flare had its onset at 0023, its maximum intensity at 0042, and a total duration of about 200 minutes. The maximum energy flux was 3×10^{-3} erg/cm^2 sec, and the time integrated flux was 97 erg/cm^2 ($2 < \lambda < 12$ A). Assuming equal intensity over 2π steradians at the sun, the total emission in this wavelength band was 1.4×10^{29} ergs, and the maximum surface luminosity of the sun was 2.0×10^{6} erg/cm^2 sec or 4.5×10^{-5} of the whole radiant luminosity of the average solar surface. Charged particles began to arrive at the satellite at 0058, or 35 minutes after the first detection of the X-ray enhancement, and remained in the interplanetary system for at least ten days thereafter. The intensity-time curve of the soft X rays is compared with those of 2700-Mhz solar radio noise flux and of ionospheric absorption at 22 Mhz as observed at Penticton.

SIMULTANEOUS OBSERVATIONS OF SOLAR PROTONS INSIDE AND OUTSIDE THE MAGNETOSPHERE

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(Received 17 April 1967)

Simultaneous observations of low-energy (~0.5 MeV) protons emitted in a solar flare of 7 July 1966 were made with detectors on board the earth satellites Explorer 33 and Injun IV, located outside and inside the earth's magnetosphere, respectively. We find that such protons have full and essentially immediate access from interplanetary space to the polar caps of the earth.

THE ASTRONOMICAL JOURNAL

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VOLUME 72 1967 September ~ No. 1352 *NUMBER 7*

Soft X-Ray ($\lambda < 14$ Å) Emission by the Sun Since 1 July 1966. J. A. VAN ALLEN, *University of Iowa.*—By means of three thin mica-window Geiger–Mueller tubes on the earth satellite Explorer 33, a nearly continuous patrol of the soft x-ray emission by the sun has been maintained with 1-min time resolution for the following periods:

1 July 1966–22 September 1966
9 October 1966–8 December 1966
27 December 1966–18 March 1967

and is continuing at the date of writing. Typical sensitivity is 10^{-6} erg (cm^2 sec)$^{-1}$ and the dynamic range of intensity is 10^4. A catalogue of x-ray flare events and detailed intensity–time profiles of selected events are presented. Four noteworthy events which are precursors of the arrival of solar-emitted particles are as follows:

Date	Time of onset	Time of max. intensity	Ratio of maximum intensity to that of ambient quiet sun
7 July 1966	00:23 UT	00:42 UT	28
28 August	15:22	15:31	70
2 September	05:46	05:58	60
13 February 1967	17:55	18:24	12

Some preliminary absolute intensities ($\lambda < 14$ Å) are (a) Mean quiet sun (September 1966): 4×10^{-4} erg (cm^2 sec)$^{-1}$. (b) Maximum intensity of 28 August 1966 event: 3×10^{-2} erg (cm^2 sec)$^{-1}$. (c) Time-integrated emission of 28 August 1966 event (assuming 2π sr at the sun): 0.7×10^{20} ergs. The x-ray flare events are intimately related to the Hα flare reports and to terrestrial SID's (sudden ionospheric disturbances).

Journal of Geophysical Research, Space Physics Vol. 73, No. 1 January 1, 1968

Observations of Protons in the Magnetosphere and Magnetotail with Explorer 33

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Protons in the magnetosphere and magnetotail were observed with a silicon detector on Explorer 33. Detectable fluxes of protons $E_p > 0.31$ Mev were measured to 10.4 R_E on the sunward side of the earth and, for the first time with the present experiment, to 80 R_E in the magnetotail. The small proton fluxes ($\lesssim 5/\text{cm}^2$ sec ster) measured in the magnetotail were usually anisotropic, with the largest flux apparently flowing down the tail, away from the earth. When proton bursts occurred in the tail, there was usually increased high-latitude magnetic bay activity at the earth. Durably trapped proton fluxes were observed to have intensities and spectra in agreement with previous measurements. A diurnal variation (in the L coordinate system) was observed in the 0.31- to 10-Mev trapped protons for $L > 6.6$ R_E.

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Special Meeting on Solar Astronomy of the American Astronomical Society, Held 1-3 February 1968 in Tucson, Arizona by the Kitt Peak National Observatory and the University of Arizona

Solar X-Ray Observations with Explorer 33, Explorer 35, and Mariner V. J. A. VAN ALLEN, J. F. DRAKE, AND SR. J. GIBSON, *Department of Physics and Astronomy, University of Iowa.*—By means of thin-windowed Geiger tube detectors nearly continuous observation of the soft x-ray emission of the whole sun has been achieved as follows:

Spacecraft	Wave-length	Time resolution	Dates of observation
Explorer 33	2–12 Å	82 sec	1 July 1966–20 Sept. 1966
		164	9 Oct. 1966– 1 Dec. 1966
		82	21 Dec. 1966– 3 Apr. 1967
		164	21 Apr. 1967–15 June 1967
		82	10 July 1967– 1 Oct. 1967
		164	20 Oct. 1967–13 Dec. 1967
		82	1 Jan. 1968–continuing as of 30 Jan. 1968
Explorer 35	2–12 Å	82	19 July 1967–continuing as of 30 Jan. 1968
(in lunar orbit: 2 to 5 hours loss per day due to lunar occultation and eclipse)			
Mariner V	2– 8 Å	101	14 June 1967–24 July 1967
		403	24 July 1967–21 Nov. 1967

A continuing catalogue of solar flares whose maximum intensity exceeds that of the ambient quiet sun by a factor greater than 4 is published in the monthly *Solar-Geophysical Data* (U. S. Dept. of Commerce). (*See also J. Geophys. Res.* **72**, 5903–5911, 1967.) The high sensitivity, large dynamic range, and continuous nature of these observations are proving of considerable value in coordinated studies of a variety of solar-geophysical phenomena —viz.: physics of solar flares, solar emission of energetic electrons, protons and alpha particles, solar emission of microwave radio noise, and ionospheric absorption and ionization phenomena. Exemplary data are presented, including the absolute intensity as a function of time for the great x-ray flares of 21 and 23 May 1967. The latter had a maximum intensity F (2 – 12 Å) = 0.65 erg (cm^2 sec)$^{-1}$ and is apparently the most intense x-ray flare ever observed.

A detailed catalogue of all reduced observations is being prepared on magnetic tape.

THE ASTROPHYSICAL JOURNAL, Vol. 152, May 1968

SOLAR X-RAY FLARES ON MAY 23, 1967

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Received April 2, 1968

ABSTRACT

The absolute flux of soft X-rays (2–12Å) from a sequence of three solar flares on May 23, 1967, is given as a function of time with a resolution of 163.6 sec. Maximum flux $F(2\text{–}12\ \text{Å}) = 0.65$ erg cm^{-2} sec^{-1} occurred at 1846 U.T. This is believed to be the most intense solar X-ray flux that has been observed.

SOLAR X-RAY CONTROL OF THE D-LAYER OF THE IONOSPHERE

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ABSTRACT

Solar X-ray control of the D-layer of the ionosphere is evaluated. 1-10 A° X rays have unit optical depth in a layer of 40 km thickness lying between 57 and 97 km above the earth. 1-10 A° flux is extrapolated from 2-12 A° flux recorded by University of Iowa detectors on Explorer 33 during the period July 1966 to September 1967. Electron production rates due to typital values of the flux are computed. Relative importance of X-ray ionization is estimated by comparing these with total D-layer electron production rate and also with computed electron production rates due to Lyman alpha and cosmic rays.

A high correlation is observed between mid-day 30 Mc/sec cosmic noise absorption over Bedford and observed 2-12 A° flux. An empirical relation is obtained between midlatitude cosmic noise absorption for frequencies higher than 20 Mc/sec and 1-10 A° flux by combining theoretical computation with the observed correlation. This relation shows that X-ray ionization, depending on the solar activity level, is responsible for 50% to 80% of the total D layer absorption.

It is concluded that 1-10 A° solar X-ray flux which varies with daily solar activity and varies by a factor of about 100 over a sunspot cycle, contributes up to 80% of the total D-layer ionization depending on the solar activity. The daily variations, as well as long term variation over a sunspot cycle, of the D-layer indices and the D-layer height are traced to the importance of X-ray ionization.

ROCKET AND SATELLITE STUDIES OF SOLAR X-RAY FLARES

By: P. R. Sengupta, Department of Physics and Astronomy
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ABSTRACT: Rocket and satellite measurements of flare X ray in different wavelength regions are studied in detail. It is confirmed that in addition to enhancement of X-ray flux in all the wavelength regions, X-ray flares are characterized by hardening of the X-ray spectrum with appearance of hard X rays in some cases. Probable flare X-ray spectral energy distribution is obtained from the spectral measurements made during past years. Correlation of X-ray flares with optical flares, radio bursts, and S.I.D.'s is considered in detail. Probable emission mechanisms are discussed and detailed analysis is presented for two hard X-ray flares to show that hard X-ray flares may be due to non-thermal bremsstrahlung of non-relativistic electrons accelerated during the 'flash' or the eruptive phase of the flare. The soft X-ray component of the flare X ray is quasi-thermal in nature. It is concluded that X-ray flares are complex in nature and belong to more than one class. Different competitive processes, viz., enhancement of thermal bremsstrahlung emission with rise in temperature, appearance of new lines, and non-thermal bremsstrahlung may simultaneously be responsible for flare emission in different wavelength regions. New experiments are suggested for better understanding of solar X-ray flares.

Corrected Absolute Flux of the July 7, 1966, Solar X-Ray Flare

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The July 7, 1966, solar X-ray flare has been described in an earlier paper [*Van Allen*, 1967]. The absolute flux F (2–12 A) in erg (cm^2 sec)$^{-1}$ is given by the formula

$$F(2\text{–}12\ \text{A}) = (1.8 \times 10^{-6}) \cdot f(\alpha) \cdot R \qquad (1)$$

where R is the properly corrected counting rate (R1X) of the detector in counts (sec)$^{-1}$ caused by solar X rays, α is the angle between the spin axis of the satellite and the satellite-sun line, and $f(\alpha)$ is the 'geometric obliquity factor.'

On July 7, 1966, the value of α (124.2°) is such that $f(\alpha)$ is a sensitive function of α, of the X-ray spectrum, and of the collimation of the beam.

In the earlier paper I adopted the best value then available for $f(\alpha)$ (= 81), as derived from preflight laboratory calibration data. Since that time, it has been possible to mutually normalize the three X-ray detectors on Explorer 33 (GM1, GM2, and GM3) and a similar one (GM1) on Explorer 35 using flight data. Moreover, since α for Explorer 35 is approximately constant at 90° ± 3°, whereas α for Explorer 33 varies continuously with time, the relative $f(\alpha)$ versus α curves for the three GM detectors on Explorer 33 have been determined by means of the simultaneous bodies of flight data from the two spacecraft, using, of course, the actual solar spectrum and the actual spread of the solar beam. Because of its superior calibration history, GM2 on Explorer 33 has been adopted as the 'standard' detector with $f(0°) = 1.00$ in equation 1. For GM1 on Explorer 33, $f(90°) = 10.8$, and

$$f(124.2°) = 470 \qquad (2)$$

the latter value being appropriate to the July 7, 1966, flare. All absolute fluxes in my earlier paper must therefore be multiplied by the factor 470/81 = 5.8.

Table 3 of that paper should be disregarded, and the scale of absolute flux on the right-hand side of Figure 6 should be shifted by the above factor. Several specific absolute quantities should be corrected to read as follows:

Pre-flare flux at 0000 UT of July 7: 6.4×10^{-3} erg (cm^2 sec)$^{-1}$.

Maximum flux at 0042 UT: 0.17 erg (cm^2 sec)$^{-1}$.

Time integral of flux from 0023 to 0345 UT: 560 ergs cm^{-2}.

Integrated X-ray ($2 < \lambda < 12$ A) energy emission of flare: 8.1×10^{29} ergs.

Maximum directional intensity of whole flare at 0042 UT: 3.9×10^{25} ergs (sec ster)$^{-1}$.

Maximum surface brightness of nominal flare area: 2.6×10^{6} erg (cm^2 sec ster)$^{-1}$.

Maximum luminosity of flare area: 1.7×10^{7} ergs (cm^2 sec)$^{-1}$ or 2.6×10^{-4} of the whole radiant luminosity of the average solar surface.

The nominal uncertainty in the foregoing absolute values is now estimated to be $\lesssim 50\%$. It is believed unlikely that they are in error, either high or low, by as much as a factor of 2.

Absolute fluxes for the three X-ray flares on May 23, 1967, stand as previously published [*Van Allen*, 1968].

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Van Allen, J. A., Solar X-ray flares on May 23, 1967, *Astrophys. J.*, *152*, L85, 1968.

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The Solar X-Ray Flare of 7 July 1966

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Abstract

A major solar X-ray flare was observed on 7 July 1966 by University of Iowa equipment on the spinning satellite Explorer 33. Details of the detector are given. The maximum intensity of the X-ray flare occurred at 0042 UT and reached a value 28 times that of the pre-flare ambient value. The X-ray flare is attributed to the McMath plage region 8362.

There is general overall resemblance to solar radio noise at 2700 MHz and detailed resemblance to ionospheric D-layer absorption of cosmic radio noise at 22 MHz.

A more detailed account is published in *J. Geophys. Res.*, 1967, **72**, 5903–5911.

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Observations of the Solar Particle Event of 7 July 1966 with University of Iowa Detectors

T. P. Armstrong, S. M. Krimigis, and J. A. Van Allen
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Abstract

Nearly complete time histories from 7 July to 17 July of the intensities of 0.31–10 MeV protons and of 2.1–17 MeV alpha particles emitted from the solar flare of 0023 UT on 7 July 1966 have been obtained with University of Iowa particle detectors on Explorer 33. The peak intensity of $3.5 \times 10^3 (cm^2\ s\ sr\ MeV)^{-1}$ of 0.82–1.9 MeV protons occurred between 1000 and 1100 UT on 8 July, approximately 34 hours after the flare. At the same time the peak intensity of 2.1–17 MeV alpha particles was 190 $(cm^2\ s\ sr)^{-1}$. The abundance ratio of protons to alpha particles has been measured for the first time in the energy range from 0.5 to 4 MeV/nucleon and is found to range from 28 to 55 in this event. The time profiles of protons and alpha particles are complex and rapid variations of proton intensities are observed to occur in times as small as 82 seconds, the interval between data samples.

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Observed Particle Effects of an Interplanetary Shock Wave on 8 July 1966

J. A. Van Allen and N. F. Ness†*
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Abstract

"At 2106 UT on 8 July 1966, a distinctive, discontinuous drop in the intensities of solar protons $E_p \sim 0.5$ MeV was observed by Explorer 33 in interplanetary space at 187,000 km in the antisolar direction from the earth. The protons had been emitted by the sun in a flare whose onset time was 0027 UT on 7 July. The intensity drop is attributed to the effects of an interplanetary shock wave whose detailed structure was observed by a triaxial flux gate magnetometer on the same satellite."

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Solar Particle Observations inside the Magnetosphere during the 7 July 1966 Proton Flare Event

S. M. Krimigis, J. A. Van Allen, and T. P. Armstrong
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Abstract

Observations of protons emitted by the 7 July 1966 solar flare at 34°N 47°W with the low-altitude–high-latitude University of Iowa satellite Injun 4 show the following: (*a*) High energy ($E_p \sim 27$ MeV) protons arrive promptly over the earth's polar caps and decay in a manner consistent with diffusive propagation. (*b*) The counting rate due to protons in the interval $0.52 \leqslant E_p \leqslant 4$ MeV and moving normal to the magnetic vector shows a *double plateau* as the satellite moves over the polar caps. (*c*) The position of the "knee" for protons in the above energy interval varies from $L \sim 7.5$ to $L \sim 6.3$ at magnetic local times of about 04.5 hours and 11.5 hours, respectively. (*d*) After the sudden commencement the latitude gap between trapped protons and solar protons disappears, suggesting that some solar protons may become trapped in the earth's radiation belts. (*e*) Simultaneous observations with similar detectors inside the magnetosphere (Injun 4) and outside the magnetosphere (Explorer 33) show that low-energy (~0.5 MeV) protons have essentially immediate access from the interplanetary space to the polar caps of the earth. Finally, the theoretical implications of these results are discussed.

C

Summary on Energetic Particles observed during the July 1966 Proton Flare Event

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Abstract

A survey of the salient points which have emerged from observations on energetic particles during the July 1966 proton flare event. These are: (*a*) relativistic electrons of energy 3–12 MeV were observed for the first time; (*b*) the ratio of protons to α particles at energy above 0.5 MeV/nucleon varies with time during the event; (*c*) low-energy protons and electrons ($E > 0.5$ MeV) are confined within a tube of force of the interplanetary magnetic field; (*d*) a bidirectional anisotropy in the stream of protons is associated with the Forbush decrease.

JOURNAL OF GEOPHYSICAL RESEARCH, SPACE PHYSICS VOL. 74, NO. 1, JANUARY 1, 1969

Particle Shadowing by the Moon

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During the period November 10–22, 1967, the earth-moon system was bathed in an isotropic, homogeneous beam of solar electrons and protons whose intensities were slowly varying functions of time. Detailed angular distribution and intensity observations of these particles and vector magnetometer observations made simultaneously by the lunar orbiting satellite Explorer 35 are combined to examine particle shadowing effects by the moon. During the observing period, the moon and Explorer 35 passed from interplanetary space through the magnetotail. Simultaneous observations were made by the earth orbiting satellite Explorer 33, which was sunward of the earth's shock front and at large radial distance from the earth during most of the observing period. The angular distributions of the intensity of both electrons and protons were accurately isotropic within the magnetotail as well as in interplanetary space. Study of 33 cases of clear *electron* shadowing and two cases of less clear shadowing suggests the following principal conclusions: (*a*) Magnetic lines of force from external sources thread through the moon in a rectilinear manner as though it did not exist. The accuracy of this statement is measured by the maximum departure from rectilinear projection that is permitted by the electron shadowing observations. This is approximately 0.1 R_M (lunar radius) in 2 R_M or 3°. (b) Electron shadowing data provide no *direct* information on the region of access of interplanetary electrons into the magnetotail but do provide an upper limit on the trans-B diffusion velocity $v_\perp$ of electrons due to all causes. In the central portion of the magnetotail during magnetically quiet conditions and for radial distances $\lesssim 64\ R_E$ (earth radius), $v_\perp \lesssim 100$ km sec^{-1} for 50 kev electrons. This upper limit requires, among other possibilities, that the transverse electric field

$$E_\perp(=Bv_\perp/c) \leq 5 \times 10^{-4} \text{ volt meter}^{-1}$$

Lunar shadowing of protons ($E_p \gtrsim 322$ kev) is also described and discussed but is of much less significance.

JOURNAL OF GEOPHYSICAL RESEARCH, SPACE PHYSICS VOL. 74, NO. 3, FEBRUARY 1, 1969

Some Observations of Energetic Electrons in the Outer Radiation Zone during Magnetic Bays

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Changes in the cutoff boundary latitude and flux of electrons $E_e > 40$ kev in the midnight sector of the outer radiation belt during periods when magnetic bays are in progress are studied in this paper from the data obtained by the University of Iowa satellite Injun 4. From this study, it is observed that (1) the outer-zone flux in the midnight sector increases without any change in the boundary latitude during the expansion phase of a magnetic bay and (2) in addition to the increase in flux, there is also an extension of the boundary to higher latitudes during the recovery phase of a magnetic bay. From these observations, it is suggested that magnetic field line merging may not play a primary role in the production of energetic auroral electrons and that acceleration of particles takes place in the outer zone itself and not far out in the magnetotail.

Journal of Geophysical Research, Space Physics Vol. 74, No. 7, April 1, 1969

Anisotropic Fluxes of Energetic Particles in the Outer Magnetosphere

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Anisotropic fluxes of energetic particles (electrons, $E \gtrsim 50$ kev; protons, $E \gtrsim 830$ kev) encountered by the satellite Explorer 33 in, and immediately adjacent to, the distant trapping region have been studied. Attention has been given to their location in the frame of reference provided by measurements of the local field. On the day side the flux is peaked at right angles to the field, whereas on the night side it is peaked along the field. Two exceptions to this rule were found, and fluxes of 'streaming' particles were found in the magnetosheath, immediately adjacent to the magnetopause. The observations are compared with previous ones and are discussed in the light of current theory.

REVIEWS OF GEOPHYSICS VOL. 7, NOS. 1, 2 FEBRUARY-MAY 1969

Charged Particles in the Magnetosphere[1]

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1. INTRODUCTION

The object of this paper is to review observational work by the University of Iowa having to do with the dynamics of the population of charged particles in the outer radiation zone of the earth's magnetosphere.

Specific topics are as follows:

a. Intensity fluctuations and apparent lifetimes of outer zone electrons having kinetic energies E_e ranging from 40 kev to several Mev.

b. Ring current particles, protons and electrons $E_p, E_e \gtrsim 200$ ev.

c. Geomagnetically trapped α particles, $2.09 \leq E_\alpha \leq 15$ Mev.

d. The electric field in the magnetospheric tail.

The spirit of the discussion is to invite attention to a number of phenomena that appear sufficiently well established and significant to merit substantial interpretative effort.

2. INTENSITY FLUCTUATIONS AND APPARENT LIFETIMES OF OUTER ZONE ELECTRONS

The earliest comprehensive study of time fluctuations of energetic electrons ($E_e \gtrsim 1.6$ Mev) in the outer radiation zone was conducted over the 14-month period from October 1959 through December 1960 with the low-altitude satellite Explorer 7 [*Van Allen and Lin*, 1960; *Chinburg*, 1960; *Forbush et al.*, 1961; *Pizzella et al.*, 1962; *Forbush et al.*, 1962].

Figures 1 and 2 show the time history of the normalized intensity for magnetic shells $L = 2.5, 2.9, 3.5, 4.1$, and 4.7 and $L = 2.2, 2.3, 2.4$, and 2.5, respectively. It is seen that fluctuations by a factor of 10 are common and that ones by a factor as great as 100 occur occasionally. A change in the character of the fluctuations occurs at $L \sim 4$. The numerous minor fluctuations at larger L values are less and less evident as one goes to smaller L. On the other hand for $2.2 \lesssim L \lesssim 4.0$, those fluctuations that do occur are of greater relative importance and of much greater durability. This pattern of time variations continues inward to $L \sim 1.5$, as shown in the original paper. Thus, it appears that the magnetic

[1] Invited review paper presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., September 3–13, 1968.

JOURNAL OF GEOPHYSICAL RESEARCH, SPACE PHYSICS VOL. 74, NO. 11, JUNE 1, 1969

The Solar Flare of July 8, 1968

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Extensive radio and optical observations of the Importance 3B solar flare of July 8, 1968, have been reported elsewhere, as have some of its terrestrial effects. See *Solar-Geophysical Data, IER-FB-288* (August 1968) and *IER-FB-293* (January 1969) (U. S. Department of Commerce).

In view of the very considerable interest in this event, we report herein our soft X-ray observations with Explorer 33 and Explorer 35 reduced to absolute flux F(2–12 A) as previously described [*Van Allen*, 1967, 1968]. No other comparable measurements are known to us.

The Hα flare data (*IER-FB-293*) are as follows:

Start: 1707 UT
Maximum phase: 1727 UT
Position: N 13°; E 59°
McMath plage region: 9503
Importance: 3B

Our best X-ray data during this period came from the lunar-orbiting Explorer 35 because of the favorable angle (94°) between the spin axis of the satellite and the satellite-sun line. An important portion of the July 8 flare was not observed with this satellite, however, because it passed into the optical shadow of the moon at 1645 and, further, was invisible from the earth for the period 1701 to 1756. Data from Explorer 33 were obtained essentially continuously throughout the event. The angle between the spin axis of Explorer 33 and the satellite-sun line was 136°. At this angle the 'geometric obliquity factor' is large (~3800) and somewhat uncertain. Hence, the absolute X-ray fluxes from Explorer 35 were adopted as the

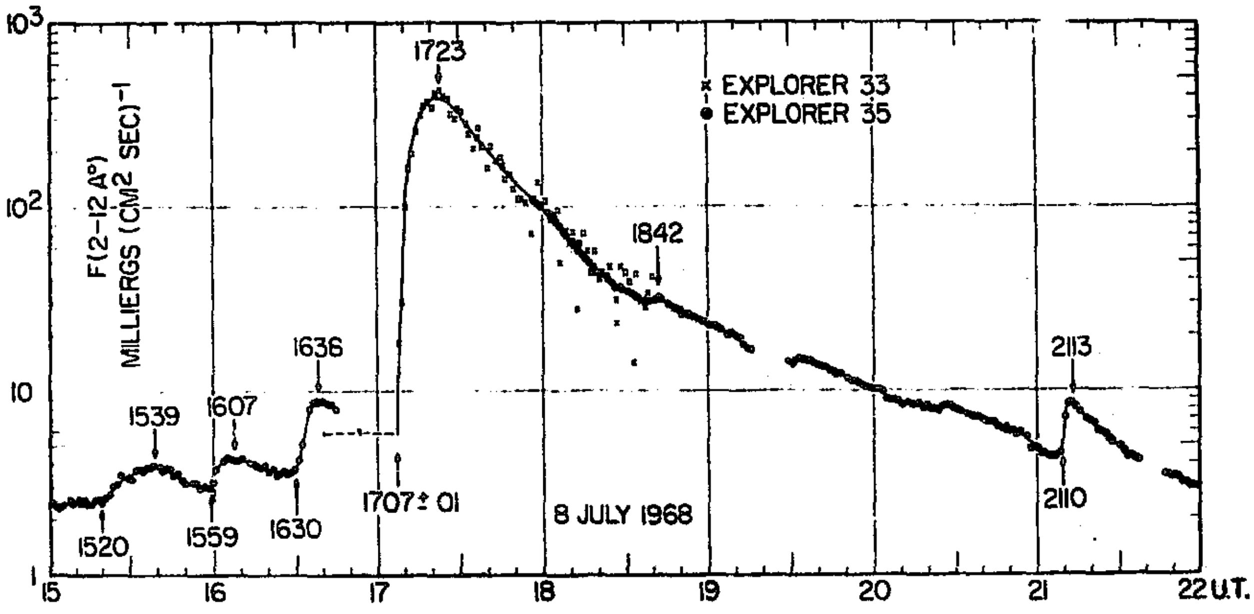

Fig. 1. Composite curve of absolute solar X-ray flux F(2–12 A) from the visible disk of the sun as observed by Explorer 33 and Explorer 35. The Explorer 35 data are of superior statistical and absolute accuracy but are absent during the period 1645 to 1756. The Explorer 33 data have been arbitrarily normalized to those from Explorer 35 during the period 1756 to 1840.

Journal of the Institution of Telecommunication Engineers, India, Vol. 15, No. 5, pp. 315-328, 1969

U. of Iowa 68-17

(Revised May 1968)

Effect of $1 < \lambda < 10$ A° Solar X-Rays on the Ionosphere Between 60 and 100 km*

by

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March 1968

*This work was supported in part by the National Aeronautics and Space Administration under Contract No. NAS5-9076.

ABSTRACT

Computations have been made in order to evaluate the ionospheric effects caused by the observed $2 < \lambda < 12$ A° x-ray quiescent flux and flare flux. Of seventy-two solar x-ray flares having F(2-12 A°) greater than 3×10^{-3} erg/cm^2 sec as recorded by the University of Iowa detector on Explorer 33 sixty-seven are found to be accompanied by reported S.I.D.'s in which the electron density of the ionosphere between 60 to 100 km undergoes a rapid increase during a few minutes. These rapid increases in electron density are presumably caused by the enhanced x-ray flux in the wavelength range $1 < \lambda < 10$ A° because softer x-rays would be completely absorbed above 100 km and harder x-rays would penetrate below 60 km without significant attenuation at higher altitudes. The altitudes for peak electron production range from 99 km for 10 A° x-rays down to 58 km for 1 A° x-rays. The electron-production rate equations have been solved using a quiescent x-ray energy spectrum and a mean flare x-ray energy spectrum derived from the work of various observers during the past nine years. The physical and chemical processes involved in the mechanism of ionization of the local atmospheric constituents according to existing models are discussed.

Distribution of the computed electron production rate and the resulting electron density with height have been plotted for quiescent and flare conditions. These plots have been compared with earlier work and available experimental data. It is confirmed that the S.I.D.'s can be explained quantitatively assuming flare x-rays as the only ionizing agent. It is further shown that under 1966 quiescent conditions x-ray ionization in the region under study is comparable to ionization by solar Lyman alpha. Solar Lyman α flux is known to be very steady varying by a factor not more than 2 between solar minima and solar maxima; while 0 - 10 A° solar x-ray flux varies greatly with solar activity (see text). Solar x-rays of wavelength below 10 A° are thus responsible for both rapid variations and day to day variations of the D region electron density. The variation of the effective height of the D region with solar activity may also be traced to the variation of 0 - 10 A° solar x-ray flux.

Journal of Geophysical Research, Space Physics Vol. 74, No. 19, September 1, 1969

Correlation of Solar Microwave and Soft X-Ray Radiation

1. The Solar Cycle and Slowly Varying Components

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The integral solar X-ray flux between 2 and 12 A was measured by the spacecrafts Injun 1, Injun 3, Explorer 33, and Explorer 35. The integral flux between 2 and 9 A was observed by the Mariner 5 spacecraft. The data from Injuns 1 and 3 and Explorers 33 and 35, when averaged in monthly intervals, show a long-term variation in activity of at least a factor of 5 between 1961 and 1969. A slowly varying component that tracks the 10-cm radio flux is observed in the X-ray flux. This X-ray flux variation, about a factor of 10, correlates with the appearance of major active regions on the solar disk. This slowly varying component correlates well with radio fluxes at frequencies greater than about 1 GHz and less well with radio fluxes at lower frequencies. The X-ray spectrum, obtained by comparing the 2 and 9 A flux with the 2 and 12 A flux, hardens during periods of high solar activity and may harden during flares, but it does not soften.

JOURNAL OF GEOPHYSICAL RESEARCH, SPACE PHYSICS VOL. 74, NO. 26, DECEMBER 1, 1969

Correlation of Solar Microwave and Soft X-Ray Radiation[1]

2. The Burst Component

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A study of the histories of solar flares observed at 2 cm at the North Liberty Radio Observatory of the University of Iowa and observed at X-ray wavelengths with Mariner 5 (2–9 A) and Explorers 33 and 35 (2–12 A) shows that 'post-burst increase' and 'gradual rise and fall' events are concurrent microwave and soft X-ray phenomena. The correlation between the X-ray flux and the radio flux is high but nonlinear. The character of the correlation is consistent with a thermal flare theory in which the volume emissivity at X-ray wavelengths is of the spectral form $(dE/d\nu) \sim \exp(-h\nu/kT)$ and the radio flux is from the same region that is optically thick with a temperature T. The correlation yields the peak flare temperature, T_p, and the flare solid angle in terms of the fractional increase in temperature relative to the peak temperature, $F = \delta T/T_p$. Comparing flare sizes with those obtained by other means (e.g., X-ray telescopes) shows $F > 0.2$. If free-free emission is assumed responsible for both the X-ray and the radio emissions, an $F \sim 0.5$ is consistent with the initial assumptions, whereas an $F \sim 1.0$ is not. Thus, temperatures typically double during a flare. Of twenty cases studied, an $F = 0.5$ yielded a mean peak temperature of 4 million degrees Kelvin and a mean effective diameter of 32 arc seconds.

SCIENCE
Reprinted from
17 October 1969, volume 166, pages 370–372

Alpha-Particle Emissivity of the Moon: An Observed Upper Limit

Abstract. *Measurements made by the moon-orbiting spacecraft Explorer 35 during 1967–1968 show that it is unlikely that the alpha-particle emissivity of the moon is greater than 0.064 per square centimeter per second per steradian and exceedingly unlikely that it is greater than 0.128, these values being respectively 0.1 and 0.2 of the provisional estimates made by Kraner* et al. *in 1966. This result implies that the abundance of uranium-238 in the outer crust (approximately a few meters thick) of the moon is much less than that typical of the earth's lithosphere, though it is consistent with the abundance of uranium-238 in terrestrial basalt or in chondritic meteorites.*

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A CATALOG OF SOLAR X-RAY FLARES (2 - 12 A°) WHOSE PEAK INTENSITY EXCEEDS THAT OF THE AMBIENT QUIET SUN BY A FACTOR GREATER THAN FOUR

by

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Explanatory Notes

Three mica-window neon-filled Geiger tubes on the satellite Explorer 33 are used to monitor soft x-ray emission of the whole disc of the sun. [See J. A. Van Allen and N. F. Ness, J. Geophys. Res., 72, 935-942, 1967, for fuller description of the apparatus.] The observations began on 1 July 1966 and provide one measurement each 81.8 seconds essentially continuously, with the exception of four 20-day periods per year during which no one of the three detectors views the sun. The absolute photon efficiency and the absolute energy flux efficiency for an x-ray beam parallel to the axis of the detector are shown in Figures 1 and 2, respectively. A geometric obliquity factor $f(\alpha)$ has been determined experimentally for each detector as a function of the angle α between the spin axis of the satellite and the satellite-sun line. The application of this factor and Figure 2 converts the counting rate of a detector to absolute energy flux units (ergs/cm^2 sec) for any assumed spectral distribution. Sensitivity of the detectors is typically about 2×10^{-6} ergs/cm^2 sec ($2 < \lambda < 12$ A°) and the dynamic range is 10^5.

The detectors are insensitive to solar ultraviolet.

The present listing of x-ray flares is independent of $f(\alpha)$ since the flares are characterized by a ratio of peak intensity to that of the ambient quiet sun. Continuous plots of all data are available.

The listings will be continued for the useful life of the satellite which is already known to exceed one year.

SATELLITE EXPLORER 33
X-RAY

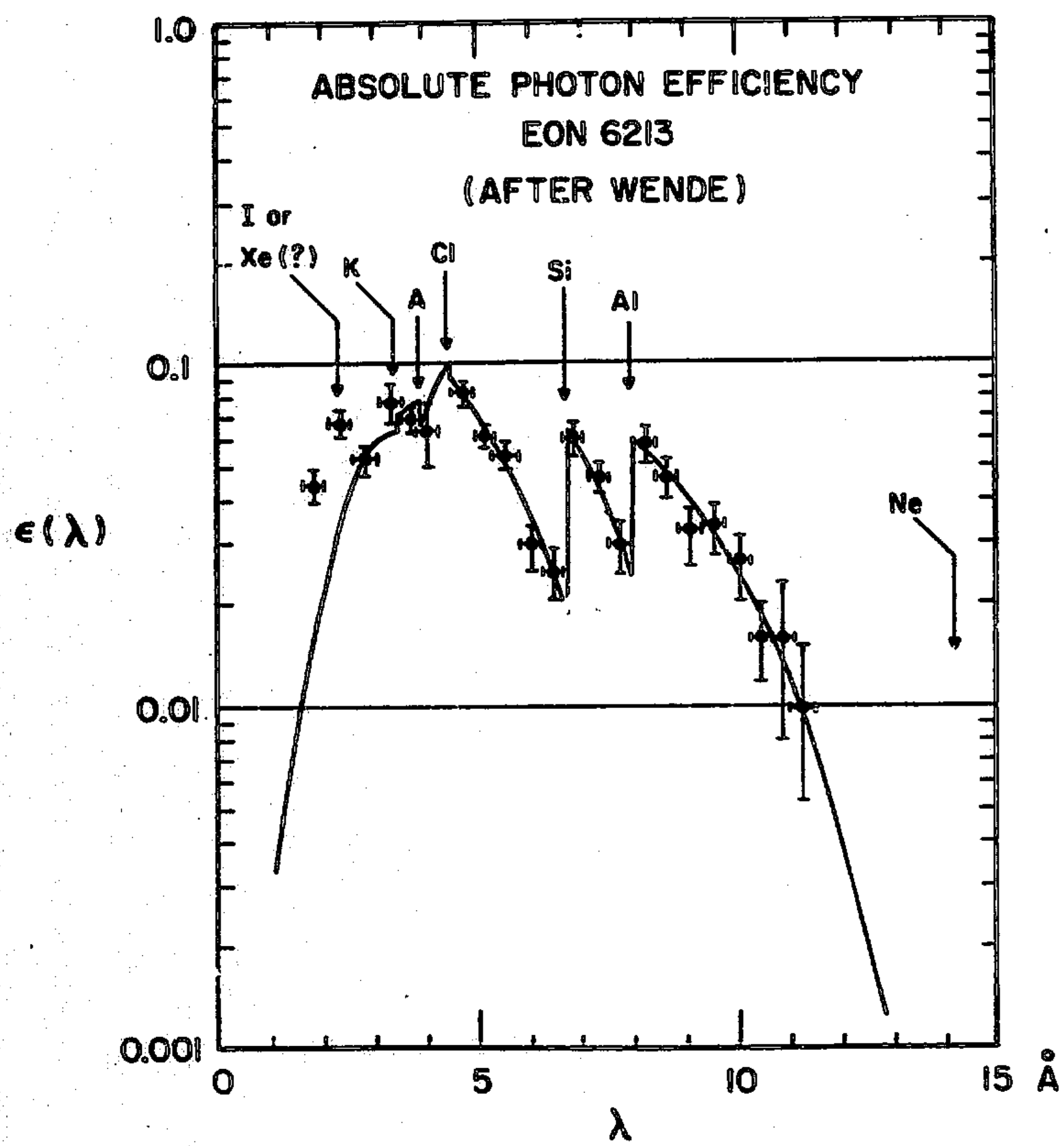

Figure 1

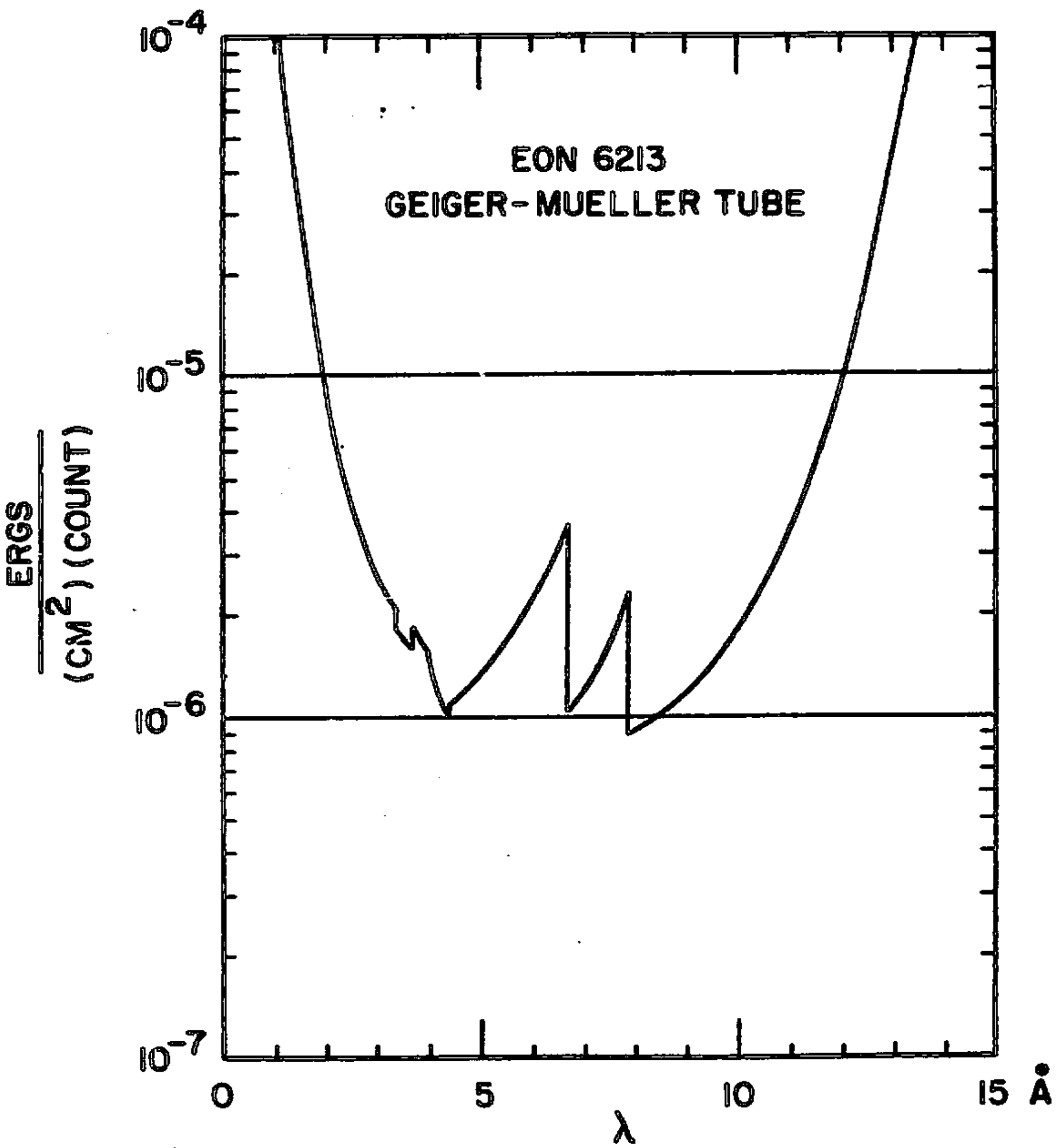

Figure 2

SATELLITE EXPLORER 33
X-RAY

Date 1966	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
7 July	0025	0042	28	
10 July	0707	0721	5	
10 July	1142	1151	4	
11 July	0857	0946	6	
21 July	1517	1526	4	Onset time uncertain
23 July	0240	0246	8	
	0931	0939	5	
25 July	1337	1400	4	
26 July	0030	0037	5	Numerous small events
	0125	0138	4	
	1007	1105	4	
	1441	1450	4	
28 July	2215	2324	13	Long decay
2 Aug.	2123	2131	7	
3 Aug.	0638	0653	4	
	1045	1104	4	
	1411	1423	4	Long flat maximum
4 Aug.				Numerous small events
5 Aug.	1150	1339	8	Slow rise, slow decay
16 Aug.	0030	0032	19	Rapid rise, rapid decay
17 Aug.	0928	1000	10	
18 Aug.	1818	1825	8	
19 Aug.	0433	0437	12	Rapid rise, rapid decay
20 Aug.	1841	1903	4	
22 Aug.				Small events
23 Aug.				Many small events
25 Aug.	0618	0624	8	
	1354	1402	7	
26 Aug.	1726	1837	5	slow rise, slow decay
	2155	2226	4	Broad max.
				Numerous small events
27 Aug.				Numerous small events
	1959	2104	4	Slow rise, slow decay
28 Aug.				Numerous small events
	1522	1531	70	
29 Aug.	0534	0545	4	
30 Aug.	1447	1509	10	
31 Aug.	0043	0101	11	
	--	0355	5	Onset time uncertain
	1825	1910	5	Slow rise, slow decay
				Numerous small events
1 Sept.				Numerous small events
2 Sept.				Numerous small events
	0546	0558	60	
3 Sept.	0325	0328	6	Rapid rise, long decay
	1358	1359	50	Rapid rise, long decay
10 Sept.				Numerous small events
12 Sept.	0907	1008	10	Numerous small events

SATELLITE EXPLORER 33
X-RAY

Date 1966	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
14 Sept.	1011	1023	14	
19 Sept.	1158	1213	7	
	1521	1528	7	
No observations from September 20, 1400UT to October 9, 0920UT.				
9 Oct.	1045	1108	4	
13 Oct.				Numerous small events
	1313	1344	21	Rapid rise, rapid decay
14 Oct.	0520	0531	33	Rapid rise, rapid decay
	--	1315	6	Onset time uncertain
				Numerous small events
15 Oct.	--	0421	4	Onset time uncertain
	1907	1925	10	Numerous small events
16 Oct.				Numerous small events
17 Oct.	0238	0315	4	
	1010	1022	7	Numerous small events
18 Oct.				Numerous small events
20 Oct.	0547	0642	4-	Slow rise, slow decay
22 Oct.				Numerous small events
	--	2220	6	Rapid rise, rapid decay
23 Oct.	0234	0240	7	Rapid rise, rapid decay
	0849	1026	17	Slow rise, complex structure
	1334	1347	4	Rapid rise, rapid decay
	1415	1436	15	
	1919	1949	4	
	2051	2108	12	
24 Oct.				Numerous small events
	2222	2301	8	
25 Oct.	0415	0426	6	
26 Oct.				Numerous small events
27 Oct.	1420	1434	4	
29 Oct.	1016	1136	9	Complex structure
30 Oct.	0140	0321	8	Complex structure
				Several small events
31 Oct.	1858	1902	4-	
1 Nov.	1052	1107	5	
2 Nov.	1703	1729	6	
5 Nov.				Numerous small events
6 Nov.	1032	1040	5	Rapid rise, rapid decay
	1331	1346	4	
7 Nov.				Numerous small events
	1731	1858	6	Slow rise, slow decay
14 Nov.	1223	1235	5	
15 Nov.	0023	0033	4	

SOLAR X-RAY FLARES (2 - 12 A°)
SATELLITE EXPLORER 33

Date 1966	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
19 Nov.	1824	1848	5	Complex Structure
22 Nov.	1831	1854	5	
No observations from 0703 to 1847 UT of 25 November due to magnetospheric traversal.				
28 Nov.	0818	0831	4	
30 Nov.	1630	1631	~12	Rapid Rise
No observations from 1 December 1600 UT to 21 December 1200 UT.				
21 Dec.	1454	1501	14	
	1933	1945	10	
No observations from 0642 to 2251 UT of 22 December due to magnetospheric traversal.				
23 Dec.	0229	0240	8	
	0750	0801	25	
	1109	1117	4	
	1309	1320	6	
	1405	1413	6	
	1503	1512	8	
	1612	1624	9	
24 Dec.	0345	0354	5	
	0440	0459	7	
25 Dec.	0210	0224	5	
	2337	2343	5	
No observations from 0001 to 0834 UT of 26 December.				
27 Dec.	1007	1011	4	
No observations from 0000 to 0838 UT of 28 December.				
28 Dec.	1759	1804	8	
No observations from 0030 to 0943 UT of 29 December.				
31 Dec.	1135	1139	4⁻	

SOLAR X-RAY FLARES (2 - 12 A°)
SATELLITE EXPLORER 33

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 Jan.	0650	0654	5	
	1033	1039	9	
4-5 Jan.	2343	0152	4^{-}	Slow rise, slow decay

No observations from 5 January 1538 UT to 6 January 1103 UT due to magnetospheric traversal.

No observations from 10 January 2259 UT to 11 January 1507 UT.

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
11 Jan.	2016	2024	8	
	-	2054	4	Onset time uncertain
12 Jan.	0226	0240	6	
	1814	1820	4	
14 Jan.	1028	1032	5	
16 Jan.	0033	0039	4^{-}	

A notably quiet period occurred from 16 January 0126 UT to 17 January 2226 UT.

No observations from 0609 to 2217 UT of 18 January due to magnetospheric traversal.

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
19 Jan.	0618	0628	6	
20 Jan.	1537	1545	10	
	1752	1803	6	
	2046	2105	4	Complex structure
21 Jan.	0835	0841	4^{-}	
	2130	2148	13	Two stage rise
22 Jan.	0630	0711	4^{-}	Complex structure
23 Jan.	1205	1206	11	Rapid rise, rapid decay
	2335	2339	4^{-}	Rapid rise, rapid decay
24 Jan.	2018	2025	5	
26 Jan.	1256	1329	5	Complex structure

Note: See explanation of this data in Miscellanea Section of IER-FB-275, July 1967. Only flares whose peak intensity exceeds that of the ambient quiet sun by a factor greater than four are listed.

SOLAR X-RAY FLARES (2 - 12 A°)
SATELLITE EXPLORER 33

University of Iowa

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
28 Jan.	0457	0552	2.5	Slow rise
	0737	0807	2.7	Slow rise. Possible precursor of particle emission
29 Jan.	1557	1622	5	Complex structure
	2219	2228	9	
30 Jan.	1124	1138	4	Slow decay
	2105	2128	5	
31 Jan.	0015	0020	5	
1 Feb.	1147	--		Small increase
	1218	1255	14	
	2306	2352	8	
3 Feb.	0258	0316	13	
4 Feb.	1641	1659	9	
5 Feb.	0012	0036	5	
	0345	0348	5	
6 Feb.	1835	1853	6	
7 Feb.	0127	0135	9	Also many smaller flares
	0622	0632	5	
	1028	1032	10	
	2051	2057	4	
8 Feb.	0305	0308	4	
	0431	0502	4	Complex structure
13 Feb.	1755	1824	12	

No observations from 1520 to 2154 UT of 14 February due to magnetospheric traversal.

SOLAR X-RAY FLARES (2 - 12 A°)
SATELLITE EXPLORER 33

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
17 Feb.	1934	1941	4	Rapid rise, rapid decay
	2211	2217	5	Rapid rise, rapid decay
18 Feb.	0938	0958	4	
	1012	1041	15	
20 Feb.	1350	1406	4	
21 Feb.	0706	0718	4	
	1700	1748	4-	Slow rise
22 Feb.	0121	0128	5	
	0352	0358	5	
	0509	0511	14	Rapid rise, rapid decay
	0621	0625	6	
	1043	1048	4	
	1415	1504	4	Complex structure
	1656	1849	0	Slow rise, complex structure
23 Feb.	0053	0111	7	Complex structure
	0546	0557	6	
	0830	0834	5	
	1141	1156	6	
	1611	1615	6	Complex structure
24 Feb.	0608	0650	8	
25 Feb.	1843	1900	4	Complex structure
	1953	2000	7	
27 Feb.	1636	1652	31	
	2116	2129	9	
1 Mar.	0425	0429	8	

No observations from 0711 to 0931 UT of 1 March due to magnetospheric traversal.

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 Mar.	0211	0217	6	Rapid rise, rapid decay
	0444	0449	4-	Rapid rise, rapid decay
	0456	0503	4	
	1544	1619	4	Complex structure

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Misc.
Mar 67

SOLAR X-RAY FLARES (2 - 12 A°)
SATELLITE EXPLORER 33

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
3 Mar.	0620	0631	9	
	0644	0651	9	
	0846	0934	4	Complex structure
4 Mar.	1211	1215	8	Rapid rise, rapid decay
5 Mar.	1008	1054	6	
A notably quiet period occurred from 1616 UT of 7 March to 2148 UT of 8 March.				
9 Mar.	1014	1036	4	
14 Mar.	2142	2146	4	
20 Mar.	--	1211	4	Onset time uncertain
22 Mar.	0023	0038	13	
27 Mar.	2110	2128	4	Complex structure
28 Mar.	1734	1739	~ 9	
29 Mar.	0718	0728	~ 5	
	1732	1737	~ 4	
30 Mar.	0022	0026	~ 6	
	0853	0900	~ 5	
31 Mar.	0411	0420	~ 4	

Notes:

1. Observations are essentially continuous with 81.8 sec time resolution except as noted.

2. Only flares whose peak-intensity exceeds that of the ambient quiet sun by a factor greater than four are listed. There are about ten times as many events that are detectable.

3. Detailed plots of the absolute intensity as a function of time for specific events can be supplied by the University of Iowa upon request (see IER-FB-275).

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Misc.
Mar-May 67

SATELLITE EXPLORER 33
SOLAR X-RAY FLARES (2-12A°)

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
31 March	2337	2409	~ 5	
1 April	0118	0131	~ 4	Also several small flares
	1409	1415	~ 8	
3 April	1434	1443	~ 7	
No observations from 2000 UT 3 April to 0000 UT 21 April due to unfavorable aspect.				
22 April	--	--	--	Several small flares
25 April	0827	0832	4-	Rapid rise, rapid decay
	0927	0936	5	
26 April	1110	1119	8	
	1243	1254	6	
	> 2119	< 2128	≳ 28	Onset and peak not observed
29 April	--	--	--	Numerous small flares
30 April	2255	2326	6	Slow rise, complex structure. Also numerous small flares
1 May	0315	0322	4-	
	0507	0522	4-	Slow rise
	1045	1048	5	Rapid rise, rapid decay
				Also numerous small flares
2 May	--	--	--	Numerous small flares
3 May	0153	0201	4	
	1434	1445	4	Complex structure
	1535	1600	18	Broad peak, slow decay
				Also numerous small flares

SATELLITE EXPLORER 33
SOLAR X-RAY FLARES (2-12A°)

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
No observations 0908 to 2152 UT 4 May due to magnetospheric traversal.				
5 May	1542	1545	5	Rapid rise, rapid decay
6 May	0427	0457	74	
7 May	2053	2103	10′	
8 May	1122	1347	7	Complex structure
	2032	2039	4⁻	
	2252	2326	4⁻	Complex structure
10 May	0711	0748	4⁻	Complex structure
	1141	1214	20	Complex structure
11 May	0929	0947	4⁻	
14 May	1526	1556	4⁻	Slow rise Numerous small flares
15 May	1008	1011	7	Rapid rise, rapid decay Also numerous small flares
16 May	--	--	--	Several small flares
17 May	--	--	--	Several small flares
18 May	0258	0344	6	Slow rise, complex structure
	1724	1858	8	Slow rise, complex structure
	2310	2401	5	Slow rise, complex structure
19 May	--	0625	4⁻	Onset not observed
	1524	1536	15	Also numerous small flares
20 May	1510	1530	5	Also numerous small flares
21 May	1238	1306	8	Complex structure
	1440	1444	4⁻	Rapid rise, rapid decay
	1534	1541	6	Rapid rise, rapid decay
	1921	1927	45	F(2-12A) = 0.18 ergs $(cm^2\ sec)^{-1}$ Most intense flare observed with Explorer 33 to date

SATELLITE EXPLORER 33
SOLAR X-RAY FLARES (2-12A)

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
21 May	2349	2417	7	Also numerous small flares
22 May	--	--		Numerous small flares

Notes:

1. Observations are essentially continuous with 81.8 sec (before 4 April) or 163.6 sec (after 21 April) time resolution except as noted.

2. Only flares whose peak intensity exceeds that of the ambient quiet sun by a factor greater than four are listed.

3. Detailed plots of the absolute intensity F(2-12A) as a function of time for specific events will be supplied by the University of Iowa upon request (see IER-FB-275).

X-ray data from Explorer 33 have been published in the Miscellanea Section of IER-FB-275 pp 125-128, IER-FB-276 pp 135-136 and IER-FB-277 pp 118-120.

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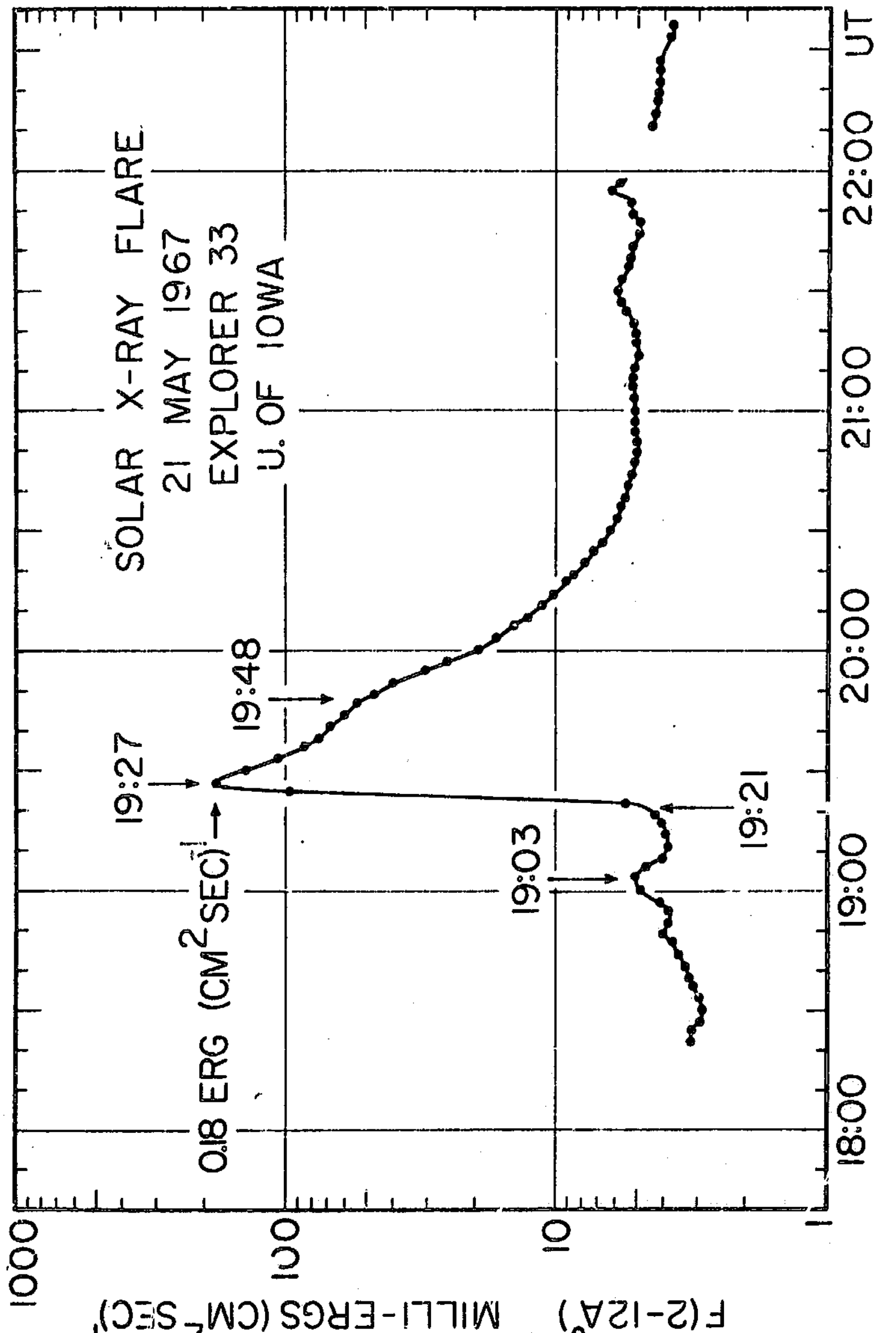

SATELLITE EXPLORER 33
SOLAR X-RAY FLARES (2 - 12 A°)

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
No observations from 0130 to 0452 UT of 22 May.				
Intermittent observations from 0320 to 1135 UT of 23 May.				
23 May	1758	1816	4	
	1834	1846	27	Maximum flux $F(2-12\ A°) = 0.65$ erg $(cm^2\ sec)^{-1}$ Most intense flare observed by Explorer 33 to date
	1934	1952	4^-	Maximum flux $F(2-12\ A°) = 0.28$ erg $(cm^2\ sec)^{-1}$
24 May	0254	0330	4	
No observations from 0456 to 0949 UT of 25 May.				
25 May	1035	1100	8	
No observations from 2158 UT of 25 May to 0006 UT of 26 May nor from 0200 to 0654 UT of 26 May.				
26 May	1235	1240	4^-	
No observations from 0159 to 0542 UT of 27 May.				
28 May	0028	0037	5	
	0528	0551	94	Maximum flux $F(2-12\ A°) = 0.32$ erg $(cm^2\ sec)^{-1}$
30 May	1728	1736	4^-	
No observations 1729 UT of 31 May to 0104 UT of 1 June due to magnetospheric traversal.				
1 June	0701	0856	4	Slow rise. Complex structure
	--	--	--	Also numerous small flares
2 June	0155	0157	4^-	
	~ 0754	0853	5	Complex structure
	1623	1709	4^-	Complex structure
	--	--	--	Also numerous small flares

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SATELLITE EXPLORER 33
SOLAR X-RAY FLARES (2 - 12 A°)

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
3 June	0228	0326	4	Slow rise, slow decay
	0554	0645	4^-	Slow rise, slow decay
5 June	1839	1945	5	Complex structure
No observations from 0259 to 0628 UT of 6 June.				
6 June	--	1220	5	Onset not observed. Complex structure
No observations from 1154 to 2335 UT of 13 June due to magnetospheric traversal.				
14 June	1334	1352	$\gtrsim 5$	
	~ 1719	~ 1727	$\gtrsim 4$	
	2237	2247	$\gtrsim 5$	
No observations from 15 June to 10 July due to unfavorable aspect.				
11 July	0124	0132	4^-	
	1948	2102	5	Slow rise, slow decay
15 July	1528	1532	4^-	
	2154	2250	4	Complex structure
16 July	2334	2347	7	
No observations from 1535 UT of 18 July to 2351 UT of 19 July due to magnetospheric traversal.				
19 July	0547	0555	4	
	0717	0739	5	Complex structure
22 July	--	--	--	Several small flares
23 July	0439	0444	4	Rapid rise, rapid decay
	0535	0542	4^-	
	0945	1007	4^-	Complex structure
	1256	1300	4	Rapid rise, rapid decay
24 July	0031	0037	8	Rapid rise, rapid decay
	0924	1000	7	Complex structure
	1146	1202	7	Complex structure
	2026	2055	12	Complex structure
	2324	2347	4	Complex structure

SATELLITE EXPLORER 33
SOLAR X-RAY FLARES (2 - 12 A°)

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
25 July	0026	0038	8	Complex structure
	1039	1057	7	Complex structure
	1212	1216	5	
	1423	1430	9	
	1621	1628	4-	Complex structure
	--	2102	4	Complex structure
	2249	2257	4-	
	--	--	--	Also numerous small flares
26 July	0223	0228	6	
	0653	0659	4	
	1343	1348	4	
	2328	2332	4	
	--	--	--	Also numerous small flares
28 July	0105	0128	5	Complex structure
	~ 1523	1607	5	Complex structure
	2229	2233	5	
29 July	2126	2136	4-	
30 July	0507	0512	4	
	0619	0627	6	
	1412	1418	4-	
No observations from 1746 UT of 30 July to 0649 UT of 31 July due to magnetospheric traversal.				
31 July	1720	1723	5	Rapid rise, rapid decay
	1949	2003	6	Complex structure
	--	--	--	Also numerous small flares

Notes:

1. Observations are essentially continuous with 163.6 sec (22 May to 15 June) or 81.8 sec (10 July to 31 July) time resolution except as noted.

2. Only flares whose peak intensity exceeds that of the ambient quiet sun by a factor greater than four are listed.

3. Detailed tabulations and plots of the absolute intensity F (2 - 12 A°) as a function of time for specific events will be supplied by the University of Iowa upon request (see IER-FB-275 and J. Geophysical Research 72, 5903-5911, 1967).

X-ray data from Explorer 33 have been published in the Miscellanea Section of IER-FB-275 pp 125-128, IER-FB-277 pp 135-136, IER-FB-278 pp 118-120 and IER-FB-280 pp 131-134.

SOLAR X-RAY FLARES (2-12A°)
SATELLITE EXPLORER 33

August 1967

University of Iowa

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 Aug.	0116	0120	4	Rapid rise, rapid decay
	0631	0638	5	Rapid rise, rapid decay
	1729	1739	23	
2 Aug.	0043	0049	20	
	2138	2143	5	Rapid rise, rapid decay
3 Aug.	0917	0932	11	Complex structure
	1628	1634	10	Rapid rise, rapid decay
4 Aug.	0135	0142	7	Complex structure
	1354	1519	14	Complex structure
	2216	2224	4	
5 Aug.	1806	1814	4⁻	
6 Aug.	0544	0600	4⁻	
	1430	1448	6	Complex structure
9 Aug.	1823	1831	10	

No observations from 1914 UT of 11 August to 0139 UT of 12 August due to magnetospheric traversal.

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
12 Aug.	0150	< 0210	4⁻	Complex structure

No observations from 1115 UT of 12 August to 0025 UT of 13 August due to magnetospheric traversal.

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
14 Aug.	1245	1257	4	Complex structure;
	-	-	-	Also numerous small flares
17 Aug.	0820	0858	5	Complex structure
	-	1008	6	Onset not observed
	1631	1640	4	

No observations from 1932 UT of 17 August to 0003 UT of 18 August.

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
18 Aug.	0043	0046	12	Rapid rise
	0221	0235	24	Complex structure, slow decay
	1923	2021	6	Slow rise
	2120	2133	18	
	2359	2406	12	

SOLAR X-RAY FLARES (2-12A°)
SATELLITE EXPLORER 33

August 1967

University of Iowa

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
19 Aug.	0529	0613	6	Slow rise, complex structure
20 Aug.	0925	0933	6	
	2022	2038	5	
21 Aug.	1830	1853	4	
22 Aug.	0156	0209	4	
	2158	2207	4-	
23 Aug.	0514	0521	7	
24 Aug.	-	-	-	Numerous small flares
	2044	2050	4	
	2323	2325	4	
No observations from 0620 UT to 1017 UT of 25 August due to magnetospheric traversal.				
25 Aug.	1406	1417	4-	
26 Aug.	0013	0024	12	
	0644	0650	4	
	2100	2114	4	
27 Aug.	0100	0104	4-	
	1525	1530	6	Rapid rise
28 Aug.	1207	1216	18	
	1411	~ 1415	4	
29 Aug.	0304	0316	6	
	1152	1238	7	Slow rise, complex structure
	1327	1333	24	
	1758	1804	5	
	1941	1949	10	
	2033	2054	12	Slow rise
30 Aug.	0012	0034	6	Complex structure
	0458	0505	7	
31 Aug.	0825	0828	5	
	2144	2150	5	

See "Notes" with September 1967 data on page 131 of this issue.

X-ray data from Explorer 33 have been published in the Miscellanea Section of IER-FB-275 pp 125-128, IER-FB-277 pp 135-136, IER-FB-278 pp 118-120, IER-FB-280 pp 131-134 and IER-FB-281 pp 151-153.

Errata: In IER-FB-281 p 152 the X-ray Flares reported as being observed by Explorer 33 on July 19 actually were observed on July 20, 1967.

SOLAR X-RAY FLARES (2-12A°)
SATELLITE EXPLORER 33

September 1967

University of Iowa

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 Sept.	0139	0143	5	
2 Sept.	2036	2041	10	
3 Sept.	2240	2245	4⁻	
4 Sept.	0308	0321	4⁻	
	0742	0755	4⁻	
9 Sept.	0244	0308	9	
10 Sept.	0852	0858	5	
	1202	1214	5	
12 Sept.	1340	1400	5	
14 Sept.	0746	0757	4⁻	
15 Sept.	1128	1147	4⁻	Complex structure
16 Sept.	0835	0913	5	Slow rise
17 Sept.	0351	0402	5	

For the period 18 through 27 September the sensitivity of the x-ray detector was degraded by the combination of particle events and unfavorable aspect. The following events during this period are the only ones that can be discerned with a good level of confidence.

18 Sept.	~ 2332	2354	~ 5	
21 Sept.	2324	2329	~ 5	
22 Sept.	0415	0418	~ 8	
	2218	2228	~ 4	
25 Sept.	2029	2036	~ 5	
	2152	2210	~ 4	
27 Sept.	0916	0924	$\gtrsim$ 5	

No observations from 28 September through 15 October due to unfavorable aspect.

Notes:

1. Observations are essentially continuous with 81.8 sec (1 August through 27 September) or 163.6 sec (16 October through 31 October) time resolution except as noted.

2. Only flares whose peak intensity exceeds that of the ambient quiet sun by a factor greater than four are listed.

3. Detailed tabulations and plots of the absolute intensity F (2 - 12 A°) as a function of time for specific periods will be supplied by the University of Iowa upon request (see IER-FB-275 and J. Geophys. Res. 72, 5903-5911, 1967).

4. Most of the gaps in Explorer 33 coverage will be filled by data from Explorer 35 and Mariner V for the following periods:

   Explorer 35: 19 July 1967 -- continuing indefinitely
   Mariner V: 14 June 1967 -- 21 November 1967

   Correspondingly revised catalogs will be published in later issues.

SOLAR X-RAY FLARES (2-12A°)
SATELLITE EXPLORER 33

October 1967

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
17 Oct	2313	2344	4^-	Slow rise, complex structure
20 Oct.	> 0000	< 0018	> 5	Onset and peak not observed
	0224	0229	7	Rapid rise, rapid decay
	0601	0616	5	Complex structure
	1131	1137	5	
21 Oct.	2053	2107	7	Complex structure
22 Oct.	0616	0623	8	
	1005	1015	20	
	1616	1627	4^-	
	2211	2220	16	
23 Oct.	0534	0542	4^-	
24 Oct.	1609	1618	8	
25 Oct.	1326	1358	4	Slow rise, slow decay
	2129	2135	4^-	
	2151	2205	10	Complex structure
	2307	2331	9	
26 Oct.	0608	0617	11	
	1013	1018	4	
	-	-	-	Also numerous small flares
27 Oct.	0819	0859	4	Complex structure
	0919	0922	5	
	0947	0959	4^-	
	1109	1114	4^-	
	-	-	-	Also numerous small flares
28 Oct.	0752	0822	4^-	Complex structure
	0841	0906	5	
	-	-	-	Also numerous small flares
29 Oct.	0216	0229	4^-	
	0257	0326	20	Slow decay
	1140	1150	4	
	2330	2404	34	Complex structure
31 Oct.	1124	1134	4	
	1520	1839	4^-	A remarkably slow rise and slow decay

*See "Notes": on page 131 of IER-FB-283 published March 1968.

SOLAR X-RAY FLARES (2 - 12A°)

SATELLITE EXPLORER 33

November 1967

University of Iowa

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 Nov.	0853	0858	27	Rapid rise, rapid decay
3 Nov.	1155	1211	16	
4 Nov.	0206	0236	4	Slow rise, complex structure
	1122	1128	4^-	
	1151	1200	8	
	--	--	--	Also numerous small flares
5 Nov.	--	--	--	Numerous small flares
6 Nov.	1233	1257	5	Complex structure
7 Nov.	0156	0201	4^-	
8 Nov.	1045	1056	6	
	1224	1306	5	Complex structure
	1957	2008	4^-	
10 Nov.	0854	0902	9	
	1157	1343	5	Slow rise, complex structure
	1525	1532	4^-	
	1823	1843	5	
11 Nov.	--	--	--	Many small flares
12 Nov.	1329	1356	6	
	1646	1651	6	Rapid rise, rapid decay
13 Nov.	1803	1818	6	
16 Nov.	1003	1012	8	
	2003	2015	5	
	2132	2152	31	
17 Nov.	0448	0456	5	Complex structure
	0819	0841	14	
	1528	1537	7	
18 Nov.	1838	1847	6	
19 Nov.	1017	1044	4^-	
21 Nov.	1452	1458	4^-	
	1647	1652	4^-	Rapid rise, rapid decay
25 Nov.	--	--	--	Numerous small flares
26 Nov.	1320	1452	5	Slow rise, slow decay
27 Nov.	0313	0319	4^-	Complex structure
29 Nov.	1312	1340	4^-	
	1609	1619	4^-	
30 Nov.	0313	0502	4^-	Complex structure
	1940	2002	8	

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Table of Contents
for Miscellaneous Data

For explanations of the data contained herein see "Descriptive Text" published in February 1968.

SOLAR X-RAY FLARES (2 - 12A°)
SATELLITES EXPLORER 33 and 35

December 1967

University of Iowa

Date 1967	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 Dec.	0310	0337	10	Gradual rise
	0456	0526	6	Complex structure
	1249	1255	5	
	1302	1306	6	
2 Dec.	0507	0551	6	Complex structure
	1237	1303	4^-	
3 Dec.	0853	1029	4^-	Slow rise, slow decline
4 Dec.	1304	1316	4^-	
8 Dec.	0625	0645	4^-	
10 Dec.	1059	1104	4^-	Rapid rise, rapid decline
11 Dec.	2156	2202	4^-	
	2211	2216	21	Rapid rise, rapid decline
	2347	2408	11	
12 Dec.	--	0241	8	Onset not observed
13 Dec.	0050	0057	7	
	0332	0338	8	
	0513	0525	4^-	
	0851	0857	9	Rapid rise, rapid decline
	1342	1404	9	
	1734	1740	7	
	2348	2401	4^-	
16 Dec.	0247	0306	8	
	0932	0959	4	Complex structure
	~1407	1429	4	
	1508	1514	4	Complex structure
	1717	1723	4	Complex structure
17 Dec.	0434	0445	4^-	
	0636	0709	6	Complex structure
	1616	1629	4	
	1834	1848	4^-	
24 Dec.	~1942	1957	8	
26 Dec.	--	--	--	Numerous small flares
27 Dec.	0838	0849	4	
No observations from 1332 of 27 December to 0244 of 28 December.				
29 Dec.	0046	0053	6	
31 Dec.	1416	1427	10	

This table replaces the one for December 1967 which was published in IER-FB-286 page 153. Explorer 35 data have been added.

SOLAR X-RAY FLARES (2 - 12A°)
SATELLITES EXPLORER 33 and 35

January 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 Jan.	0327	0352	30	
	1109	1123	12	
2 Jan.	0520	0524	100	Most intense X-ray flare since May 1967. Maximum flux F(2-12A°) = 0.46 erg $(cm^2\ sec)^{-1}$
4 Jan.	2237	2243	5	
6 Jan.	2000	2004	5	
7 Jan.	2152	2200	4	
	2242	2246	4	
8 Jan.	0012	0016	8	Rapid rise, rapid decline
	0508	0512	8	Rapid rise, rapid decline
10 Jan.	0613	0619	4	
	2144	2153	4^-	
11 Jan.	1658	1703	8	
12 Jan.	1806	1813	7	
14 Jan.	0723	0733	10	
	2007	2015	12	
15 Jan.	0000	0010	10	
	1223	1228	8	
	1253	1257	5	
	1338	1343	6	
16 Jan.	1539	1546	4	
17 Jan.	0509	0524	7	
	0740	0749	7	
	1223	1240	4	
18 Jan.	0612	0619	4^-	
	1513	1528	8	Complex structure
19 Jan.	--	--	--	An unusually quiet day
21 Jan.	--	--	--	An unusually quiet day
22 Jan.	0439	0446	4^-	
24 Jan.	0424	0436	4	
28 Jan.	0839	0901	5	Very slow decline after maximum (~1 day)
29 Jan.	0800	0813	13	
	1537	1543	12	
30 Jan.	0501	0506	35	Rapid rise, rapid decline

SOLAR X-RAY FLARES (2 - 12A°)
SATELLITES EXPLORER 33 and 35

February 1968

University of Iowa

Date	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 Feb.	0929	0947	4*	
	1054	1125	5	
	1758	1805	5	
	1811	1818	4	
	1916	1920	7	
2 Feb.	0228	0230	4*	Rapid rise, rapid decline
	0258	0303	6	Rapid rise, rapid decline
	0541	0548	7	
	0917	0924	5	Rapid rise, rapid decline
	1025	1106	7	Slow rise, complex structure
5 Feb.	0818	0826	4*	
10 Feb.	1356	1359	4	
	1606	1636	7	
	1914	1927	9	
11 Feb.	0334	0344	5	
13 Feb.	2257	2304	4	
14 Feb.	0414	0420	9	Rapid rise, rapid decline
	1039	1044	7	
	1533	1536	7	Rapid rise, rapid decline
15 Feb.	0033	0043	4	
	0301	0305	6	Rapid rise, rapid decline
	1452	1509	12	
16 Feb.	1600	1607	8	
	2010	2018	7	
17 Feb.	0251	0256	8	
	0932	0936	4	
	1255	1259	10	Rapid rise, rapid decline
	2344	2357	6	Complex structure
18 Feb.	1522	1553	5	
19 Feb.	0305	0324	8	Slow decline
20 Feb.	0440	0515	8	Slow rise, slow decline
	2053	2140	4*	Complex structure
21 Feb.	0706	0731	6	
	2006	2047	6	Slow rise, slow decline
25 Feb.	0346	0405	5	
	2143	2151	4*	
	2217	2224	4	
26 Feb.	0612	0628	5	
	0815	0823	5	
28 Feb.	1936	1939	4	

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SOLAR X-RAY FLARES (2 - 12A°)
SATELLITES EXPLORER 33 and 35

March 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 March	1410	1412	7	Rapid rise, rapid decline
	2237	2244	11	
4 March	1709	1724	4	
8 March	--	--	--	An unusually quiet day
13 March	0642	0647	6	
15 March	1113	1126	5	
17 March	1749	1803	7	
18 March	--	--	--	An unusually quiet day
20 March	1959	2605	4	Very slow rise and very slow decline
21 March	1419	1429	6	
	1913	1917	20	Rapid rise, rapid decline
	2200	2209	8	
22 March	--	--	--	Numerous small flares
23 March	0934	0940	8	Rapid rise, rapid decline
	2126	2134	4-	
24 March	0744	0753	10	(Note 1)
	0850	0852	5	
	1634	1646	11	(Note 1)
25 March	1501	1507	10	(Note 1)
27 March	1331	1344	4-	
	1758	1816	4	Complex structure

Note 1: These three X-ray flares, all apparently from McMath plage region 9273, have a remarkable similarity in their intensity-time profiles and in their maximum absolute intensities.

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

April 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 April	1307	1309	4	Rapid rise, rapid decline
3 April	0544	0554	~ 7	
	2042	~ 2048	~ 4	
4 April	~ 0255	~ 0305	~ 4	
	0809	0828	4^-	
	1858	1906	4^-	
5 April	1303	1310	4	Complex structure
	1949	1953	4	
	2147	2217	4^-	Complex structure
6 April	0704	0711	6	
10 April	1606	1632	4	Complex structure
11 April	1141	1152	4^-	
19 April	1609	1614	4^-	
	1628	1706	4^-	Slow rise, slow decline
22 April	> 1753	< 1910	> 8	Onset and peak not observed
25 April	0036	0047	10	
	0714	0751	4^-	Complex structure
28 April	--	--	--	Many small flares
29 April	--	--	--	Many small flares
	1900	1915	4	

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May 68

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

May 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 May	1726	1746	4⁻	
	1943	1946	4⁻	Rapid rise, rapid decline
2 May	2050	2055	4⁻	Rapid rise, rapid decline
3 May	2124	> 2129	> 13	Peak not observed
4 May	1510	1528	5	
5 May	0426	0429	4	Rapid rise, rapid decline
	0551	0614	5	
7 May	0154	0204	4	
10 May	1936	1940	4	Rapid rise, rapid decline
	2109	2115	4⁻	
12 May	0817	0826	5	
18 May	1149	1152	4	Rapid rise, rapid decline
	1202	1207	4⁻	
21 May	1950	2020	4	
24 May	2200	2223	4	

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

June 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 June	1627	1631	4	Rapid rise, rapid decline
3 June	0256	0300	6	
	2331	2341	6	Complex structure
4 June	> 0847	0904	7	Onset not observed
	1015	1027	10	
	2306	2329	4-	Complex structure
5 June	1223	1228	4	
	2048	2055	6	
7 June	0254	0336	6	Slow rise, complex structure
	--	1306	4	Slow rise, slow decline, onset not observed
8 June	1727	1823	4-	Slow rise, slow decline
	2033	2039	4	
9 June	0025	0042	10	
	0834	0901	18	
10 June	2206	2212	4	Complex structure
11 June	0306	0319	6	
	0932	0938	15	
13 June	1033	1039	4	
14 June	2325	2655	4-	Very slow rise and decline
15 June	2148	2201	7	
17 June	0247	0309	5	Complex structure
18 June	2022	2040	5	
19 June	1726	1756	6	(Uncertain)
	2040	2052	4	
	2224	2230	8	
	2336	2348	4-	
20 June	0225	0229	4	
	0904	0924	4	
	1703	1708	4	
27 June	0725	0729	5	
30 June	1832	1907	5	Complex structure

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

July 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 July	0743	0755	4^-	
3 July	0854	0902	6	
	2329	2332	9	Rapid rise, rapid decline
	2341	2349	4	
4 July	1129	1152	9	Complex rise
5 July	1544	1556	4	Complex structure
6 July	0941	0950	120	Maximum flux F (2-12 A°) = 0.28 erg $(cm^2 \ sec)^{-1}$
	1550	1554	4^-	
7 July	1624	~ 1804	~ 4	Slow rise, complex structure
8 July	1708	1721	150	Maximum flux F (2-12 A°) = 0.32 erg $(cm^2 \ sec)^{-1}$
9 July	1806	1822	12	
10 July	2259	2326	4	Complex structure
11 July	2359	2415	13	
	--	--	--	Also considerable minor X-ray activity
12 July	1341	1414	6	
14 July	0019	0021	5	
20 July	0813	0834	5	
26 July	2027	2046	4	Complex structure
27 July	0620	0639	4	Complex structure
28 July	0717	0723	6	
29 July	1049	1052	5	Rapid rise, rapid decline
30 July	0517	0519	4^-	Rapid rise, rapid decline
	2027	2032	7	
31 July	1719	1723	4^-	Rapid rise, rapid decline

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

August 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 August	0732	0741	4	
3 August	0310	0326	44	Maximum flux F(2-12 A°) = 0.090 ergs $(cm^2\ sec)^{-1}$
5 August	1429	1434	5	
	1441	1449	4	
6 August	1127	1138	4	
	1309	1338	17	
7 August	0144	0148	4	Rapid rise, rapid decline
	0401	0404	7	Rapid rise, rapid decline
	2349	2357	8	
8 August	0250	0259	40	Maximum flux F(2-12 A°) = 0.053 ergs $(cm^2\ sec)^{-1}$
	0614	0638	43	Maximum flux F(2-12 A°) = 0.060 ergs $(cm^2\ sec)^{-1}$
	1312	1320	22	Complex structure
	1436	1446	8	
	1601	1606	4	Rapid rise, rapid decline
	1813	1820	130	Maximum flux F(2-12 A°) = 0.16 ergs $(cm^2\ sec)^{-1}$
9 August	1606	1611	10	Rapid rise, complex structure
10 August	0006	0140	4	Slow rise, complex structure
11 August	0742	0823	6	
	1634	1652	7	Complex structure
13 August	1253	1257	6	Rapid rise, rapid decline
14 August	0030	0047	4-	
	0201	0243	4	
	0940	0945	4	
	1324	1352	20	Maximum flux F(2-12 A°) = 0.064 ergs $(cm^2\ sec)^{-1}$
17 August	0113	0229	4-	Complex structure, very slow decline
18 August	1326	1337	4-	
20 August	--	--	--	Many small flares
	2315	2318	4-	
21 August	0146	0150	28	Rapid rise and rapid decline, followed by slow decline
	0654	07 2	17	
	0817	0832	8	
	1532	1539	7	
	1833	1842	20	
	1929	1938	24	
	2352	2358	4-	
	--	--	--	Also many small flares
22 August	--	--	--	Many small flares
23 August	0325	0329	5	Rapid rise, slow decline
	1104	1113	13	
	1125	1133	8	
	1456	1502	13	
	2345	2349	4-	
24 August	0352	0357	4-	
	0633	0634	10	Brief spike superimposed on broad, low maximum
26 August	1851	1909	4-	Complex structure
29 August	0030	0043	12	
	0425	0432	6	
	0837	0845	11	
30 August	0237	0244	12	
	0349	0356	4	
	1011	1144	6	Slow rise, slow decline

S O L A R X-R A Y R A D I A T I O N

University of Iowa - Explorer 33 -- This satellite is in an eccentric orbit about the earth with perigee and apogee currently at radial distances of about 29 and 75 earth radii, respectively. It spins at a rate of about 22 rpm about an axis lying in an approximately constant inertial direction within a few degrees of the ecliptic plane. Data transmission and reception are continuous. Three mica-window neon-filled Geiger tubes on the satellite Explorer 33 are used to monitor soft x-ray emission of the whole disc of the sun. [See J. A. Van Allen, J. Geophys. Res., 72, 5903-5911, 1967 and ibid., 73, 6863, 1968, for fuller description of the apparatus.] The observations began on 1 July 1966 and provide one measurement each 81.8 seconds essentially continuously, with the exception of four 20-day periods per year during which no one of the three detectors views the sun. The absolute photon efficiency and the absolute energy flux efficiency for an x-ray beam parallel to the axis of the detector are shown in Figures 1 and 2, respectively. A geometric obliquity factor $f(\alpha)$ has been determined experimentally for each detector as a function of the angle α between the spin axis of the satellite and the satellite-sun line. The application of this factor and Figure 2 converts the counting rate of a detector to absolute energy flux units (ergs/cm^2 sec) for any assumed spectral distribution. Sensitivity of the detectors is typically about 2×10^{-5} ergs/cm^2 sec ($2 < \lambda < 12$ Å) and the dynamic range is 10^5.

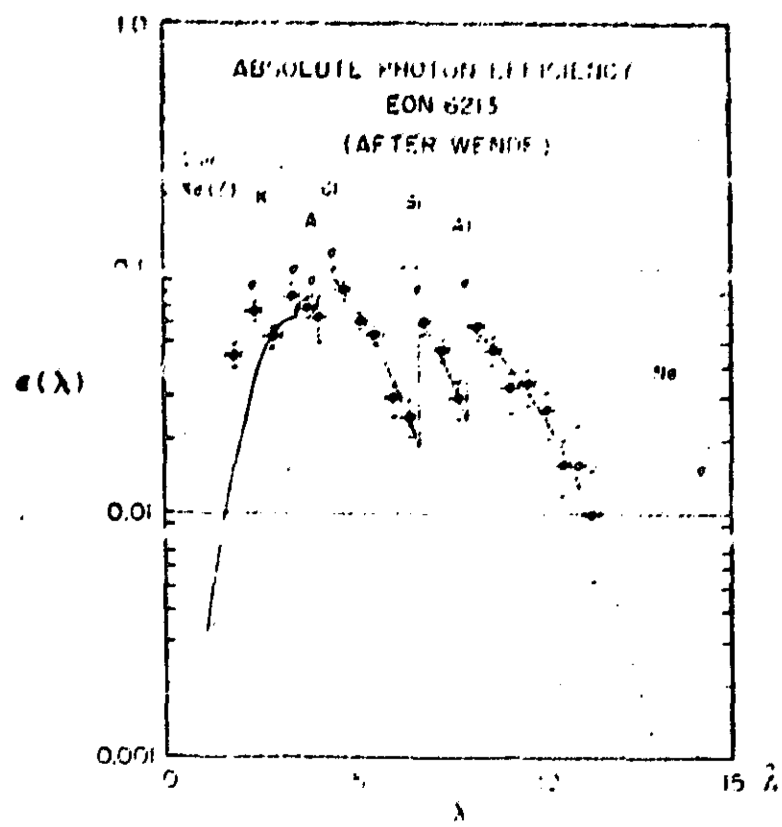
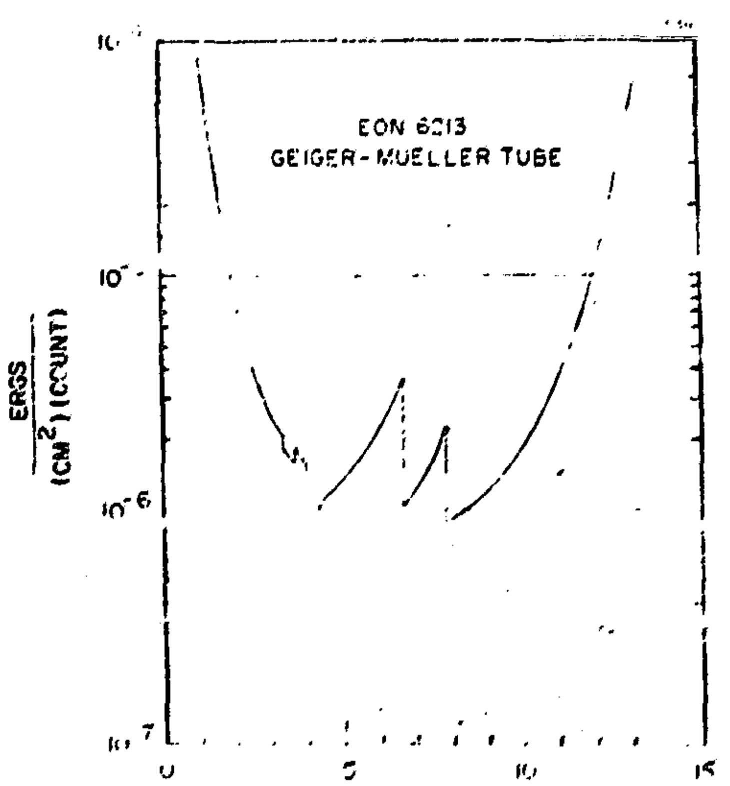


Figure 1



The detectors are insensitive to solar ultraviolet.

The present listing of x-ray flares is independent of $f(\alpha)$ since the flares are characterized by a ratio of peak intensity to that of the ambient quiet sun. The monthly listing gives brief data for each flare whose maximum intensity exceeds the intensity of the ambient quiet sun by a factor greater than four. For each event the time of onset (UT), time of maximum (UT), and peak ratio to the quiet sun value existing before the burst occurs are given together with descriptive remarks. About ten times as many flares of lesser intensity are identifiable.

University of Iowa - Explorer 35 -- This satellite carries solar x-ray detectors similar to those on Explorer 33. This is in an orbit about the moon with periselene and aposelene radial distances of 1.5 and 5.3 lunar radii, respectively. The spin axis of the satellite is directed approximately toward the south ecliptic pole. Hence, the geometric obliquity factor $f(\alpha)$ is essentially constant. Solar observations are continuous with the exception of periods totaling 1 to 2 hours per day during eclipse and occultation by the moon.

Explorer 35 was launched on 19 July 1967 and placed in lunar orbit on 22 July 1967.

Current monthly listings of solar x-ray flares (in the same format as those for Explorer 33) are principally from Explorer 35 with minor gaps filled in by data from Explorer 33. Hence, the coverage is essentially continuous in time with a resolution of 81.8 sec. The listings will be continued for the useful life of the equipment (already 30 months for Explorer 33 and 18 months for Explorer 35). Detailed catalogs and machine plots of all observation (in absolute intensity) are available. Requests for data for specific periods should be directed to J. A. Van Allen, Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52240 and after 1 July 1969 to the National Space Science Data Center, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland 20771.

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SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

September 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 September	0643	0713	5	Note 1
	1606	1630	6	Note 1
3 September	1617	1628	4	Complex structure
4 September	0030	0053	9	Double peak, slow decline
	--	0112	10	
	1119	1211	4^-	Slow rise, complex structure
	1320	1324	4^-	Double peak
	--	1336	4	
	2157	2200	5	Rapid rise, complex structure
5 September	0112	0115	4	Rapid rise, rapid decline
	1458	1506	4^-	
6 September	0917	0921	4	Rapid rise, rapid decline
	1432	1447	4^-	Complex structure
8 September	> 0106	< 0118	> 14	Onset and peak not observed
	1158	1211	4	
	1234	1239	5	
9 September	0116	0123	6	
	0234	0246	9	
	1844	1853	4	Slow decline
10 September	0320	0341	4	
	1142	1148	6	
	2010	2020	4^-	
11 September	0013	0016	4^-	Rapid rise, rapid decline
	2351	2424	6	Slow rise, slow decline
13 September	0849	0900	9	
16 September	--	--	--	Notably quiet day
17 September	2027	2031	5	
19 September	0508	0512	4	

Note 1: These two flares have almost identical flux-time profiles in detail and nearly the same absolute flux.

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

September 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
21 September	0302	0306	6	Rapid rise, rapid decline
	1041	1106	4⁻	
22 September	0846	0853	4	
23 September	0514	0550	4	Slow rise, slow decline
25 September	~ 1312	1457	9	Very slow rise and decline
26 September	0025	0034	17	
	1035	1124	4	Complex structure
27 September	1033	1039	4	Rapid rise, rapid decline
28 September	> 0143	0207	17	Onset not observed
	0718	0829	13	Very slow rise and decline
29 September	0925	0942	10	
	1616	1624	22	
30 September	0630	~ 0712	~ 5	Peak not observed
	1227	1237	4⁻	
	2216	2230	9	

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

October 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 October	0240	0323	7	
	> 1950	2020	19	Onset not observed
3 October	2344	> 2411	≳ 13	Peak not observed
4 October	1837	1902	5	Complex structure
	--	2155	4	Onset not observed
5 October	0234	0249	4	
	1421	1437	6	
6 October	1721	1736	6	
10 October	1024	1139	5	Slow rise, complex structure
11 October	0459	0502	4	Rapid rise, double peak
	2321	2334	4	
12 October	1338	1344	4	
	2003	2007	5	
13 October	0642	0652	5	
	1334	1353	5	
14 October	--	--	--	Quiet day
15 October	--	2213	4	Onset not observed
16 October	0010	0019	4	
	0444	0523	7	Complex structure
	0746	0755	7	
	1040	1058	4	
	1508	1516	4	
	--	--	--	Also numerous small flares
17 October	--	1647	4	Onset not observed
	--	--	--	Also numerous small flares
18 October	--	< 0418	> 10	Onset and peak not observed
	0937	0940	13	Rapid rise, slow decline
	2129	2137	4	
	2336	2341	4	
19 October	0036	0202	5	Slow rise, complex structure
	0436	0447	4	
	0937	0955	4	
	0959	1012	8	
	351	1859	4	
	--	--	--	Also numerous small flares
20 October	0650	0704	12	Complex rise
	1928	1933	4	
	1941	1945	4	
	2127	2131	8	
	--	--	--	Also numerous small flares

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SOLAR X-RAY FLARES (12-12A°)
SATELLITES EXPLORER 33 and 35

October 1968

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
21 October	0248	0258	4	
	0456	0508	11	
	0604	0609	35	Maximum flux, F(2-12 A°) = 0.114 erg $(cm^2 \ sec)^{-1}$
	0820	0826	4	
	1123	1130	5	Complex structure
	1424	1435	8	
	1726	1734	20	
	2123	2130	7	
	--	--	--	Also numerous small flares
22 October	0139	0145	5	
	0442	0447	[illegible]	
	0738	0745	4-	
	1657	1702	4	
	--	--	--	Also numerous small flares
23 October	0357	0359	16	Rapid rise, complex structure
	0857	0902	4	
	1740	1746	4-	
	1936	1941	5	
	2351	2420	39	Note 1. Maximum flux, F(2-12 A°) = 0.128 erg $(cm^2 \ sec)^{-1}$
24 October	2054	2124	14	Note 1. Maximum flux, F(2-12 A°) = 0.032 erg $(cm^2 \ sec)^{-1}$
26 October	0107	0127	4	
	1638	1653	6	
	2355	2414	9	Complex structure
27 October	0103	0200	5	Slow rise, slow decline
	1104	1112	4-	
	1142	1149	4	
	1234	1243	24	Maximum flux, F(2-12 A°) = 0.057 erg $(cm^2 \ sec)^{-1}$
	1307	1341	34	Slow rise, slow decline Maximum flux, F(2-12 A°) = 0.088 erg $(cm^2 \ sec)^{-1}$
	2208	2216	5	
28 October	0502	0513	4-	
29 October	0853	0912	5	
	0944	0959	4	
	1212	1237	12	Slow decline
30 October	0134	0138	4-	
	1238	1301	7	
	1331	1401	7	Slow rise, slow decline
	2341	2417	42	Maximum flux, F(2-12 A°) = 0.128 erg $(cm^2 \ sec)^{-1}$
31 October	2226	2308	22	Maximum flux, F(2-12 A°) = 0.079 erg $(cm^2 \ sec)^{-1}$

Note 1. Homologous in flux-time profile.

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Nov 68

SOLAR X-RAY FLARES (2-12A°)
SATELLITES EXPLORER 33 and 35

November 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 November	0801	0915	12	Slow rise, slow decline
	1958	2008	24	
	2242	2250	4	
2 November	0947	1005	36	Precursor onset at 0925
	--	--	--	Also numerous small flares
3 November	0712	0717	4-	
	1233	1239	8	
	2039	2042	7	
	--	--	--	Also numerous small flares
4 November	0514 (0458)	0529	54	Slow rise began at 0458, then a rapid onset at 0514 Maximum flux, F(2-12 A°) = 0.29 erg $(cm^2 sec)^{-1}$
5 November	1341	1347	5	
	2011	2109	5	Slow rise, slow decline
11 November	1323	1325	4	Rapid rise, rapid decline
	1443	1451	4	
12 November	1421	1431	7	
13 November	2109	2114	11	
	2140	2155	5	
14 November	2037	2049	9	
15 November	1027	1036	5	
18 November	0418	0443	6	
	1026	1057	110	Maximum flux, F(2-12 A°) = 0.25 erg $(cm^2 sec)^{-1}$, very slow decline
	2312	2316	4	
21 November	0033	0043	4	
22 November	0033	0145	4-	Slow rise and very slow decline
23 November	0538	0543	4	
	1321	1323	6	
	1653	1656	4-	
24 November	1040	1045	4-	
	1410	1421	4-	
25 November	1234	1248	4	
27 November	1115	1126	5	

Solar X-Ray Flares (2-12 A°)
Satellites Explorer 33 and Explorer 35
December 1968

University of Iowa

Date 1968	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 December	1721	1732	4	
	1934	1959	6	Complex rise
	2102	2123	20	Slow decline
4 December	1542	1548	6	
	--	--	--	Also numerous small flares
9 December	0610	0620	7	
11 December	1147	1202	5	
14 December	> 2234	2246	6	Onset not observed
15 December	2210	2219	5	
17 December	1437	1458	4-	
	1543	1552	4	
	--	< 1809	4	Early phase not observed
	--	--	--	Also numerous small flares
18 December	0430	> 0447	6	Superimposed on complex structure
	1907	1914	4	
	--	--	--	Also numerous small flares
20 December	0742	0800	4-	
	1937	1958	5	
21 December	1219	1234	4	
	1414	1419	4	
22 December	0839	> 0849	--	Peak not observed
	1942	> 1950	> 4	Peak not observed
24 December	1936	1944	5	Complex decline
25 December	--	0648	5	Onset not observed --Note 1
	1836	1844	4	Complex decline --Note 1
26 December	0807	0814	4-	
	0937	0955	4-	
	1833	1841	4	Note 1
27 December	0311	0319	5	
	--	< 1115	> 7	Early phase not observed
	2012	2020	4-	
28 December	0520	0528	7	
	--	0742	> 4	Early phase not observed
	1124	1131	9	
	2053	2105	5	Complex structure
29 December	1919	1936	35	Maximum flux F(2-12 A°) = 0.090 erg $(cm^2 \text{ sec})^{-1}$

Note 1. Similar absolute intensity-time profiles.

Solar X-Ray Flares (2-12 A°)

Satellites Explorer 33 and Explorer 35

January 1969

University of Iowa

Date 1969	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
3 January	0430	0501	11	
4 January	1300	1312	4−	Complex structure
	2056	2115	28	Maximum flux F(2-12 A°) = 0.060 erg $(cm^2\ sec)^{-1}$
6 January	0906	0913	10	Note 1
7 January	0551	0556	6	Note 1
8 January	0100	0107	3	Note 2
	1726	1734	4	Note 2
9 January	0132	0137	4	Note 3
	0510	0515	4	Note 3
	1322	1412	4	Complex structure
	1828	1840	~ 5	
13 January	--	0312	≳ 5	Onset not observed
15 January	1906	1910	4−	
16 January	1321	1326	4	
17 January	1244	1249	15	Rapid rise, rapid decline Note 4
	1703	1706	15	Rapid rise, rapid decline Note 4
18 January	0810	0821	5	
	0933	0940	4	
	1221	1228	50	Rapid rise, rapid decline Maximum flux F(2-12 A°) = 0.14 erg $(cm^2\ sec)^{-1}$
21 January	0651	0732	8	Slow rise, slow decline
24 January	0658	0740	30	Maximum flux F(2-12 A°) = 0.050 erg $(cm^2\ sec)^{-1}$
25 January	1408	1412	8	
	--	--	--	Also many small flares
27 January	0732	0742	4	
30 January	1427	1436	5	

Notes 1, 2, 3, and 4:
Sets of homologous flares.

SOLAR X-RAY FLARES (2-12 A°)
SATELLITES EXPLORER 33 AND EXPLORER 35

FEBRUARY 1969

University of Iowa

Date 1969	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 February	2132	2142	50	Rapid rise, rapid decline Maximum flux F(2-12 A°) = 0.14 erg $(cm^2\ sec)^{-1}$ Note 1
2 February	0508	0517	28	Rapid rise, rapid decline Maximum flux F(2-12 A°) = 0.056 erg $(cm^2\ sec)^{-1}$ Note 1
3 February	0159	0202	5	Rapid rise, rapid decline
	0728	0735	11	Rapid rise, rapid decline
4 February	2111	2154	4-	
5 February	1259	1345	4	Complex structure
6 February	< 0726	0751	8	Onset not observed
	2228	2233	4-	
7 February	0129	0131	4	
	0520	0527	13	
	1642	1648	7	
	2218	2226	6	
8 February	0413	0418	6	
	1204	1207	18	Rapid rise, rapid decline Note 2
	1749	1756	16	Rapid rise, rapid decline Note 2
9 February	0657	0701	9	Rapid rise, rapid decline Note 2
	1349	1356	> 4	Peak not observed
	1430	1435	7	
	1558	1608	6	
	1723	1725	54	Rapid rise, rapid decline Maximum flux F(2-12 A°) = 0.073 erg $(cm^2\ sec)^{-1}$
10 February	0343	0346	5	
	1114	1124	4	
	1933	1936	4	Exceptionally brief flare.
	2103	2112	5	
11 February	1035	1040	28	Rapid rise, complex decline
	1239	1252	6	
	2050	≈ 2118	≈ 9	Peak not observed

Notes 1 and 2: Sets of homologous flares.

SOLAR X-RAY FLARES (2-12 A°)
SATELLITES EXPLORER 33 AND EXPLORER 35

FEBRUARY 1969

Date 1969	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
13 February	1627	1638	7	
	2010	2014	5	
14 February	0334	0338	6	
	1120	1123	12	Preceded by very gradual rise
16 February	--	--	--	Notably quiet day
17 February	--	--	--	Notably quiet day
19 February	1051	1104	4	Complex rise
	1641	1702	4-	Complex rise
	2040	2048	4	
20 February	0618	0622	28	Rapid rise Maximum flux F(2-12 A°) = 0.060 erg $(cm^2\ sec)^{-1}$
	0808	0811	4-	
	1137	1145	4-	
23 February	0442	0451	9	
24 February	2035	2040	4-	
	2306	2322	22	Maximum flux F(2-12 A°) = 0.090 erg $(cm^2\ sec)^{-1}$
25 February	0607	0619	4-	
	0856	0918	90	Maximum flux F(2-12 A°) = 0.38 erg $(cm^2\ sec)^{-1}$
	1936	1956	7	Maximum flux F(2-12 A°) = 0.030 erg $(cm^2\ sec)^{-1}$
26 February	0414	0430	55	Maximum flux F(2-12 A°) = 0.26 erg $(cm^2\ sec)^{-1}$
	0548	0613	8	Maximum flux F(2-12 A°) = 0.039 erg $(cm^2\ sec)^{-1}$
27 February	1037	1050	8	
	1245	1257	5	
	1356	1412	70	Maximum flux F(2-12 A°) = 0.30 erg $(cm^2\ sec)^{-1}$
28 February	0135	0156	4-	
	1336	1356	4-	Complex rise
	1858	1926	4-	Complex rise
	1938	2002	11	Complex structure
	2030	2045	5	

SOLAR X-RAY FLARES (2-12 A°)
SATELLITES EXPLORER 33 AND EXPLORER 35

MARCH 1969

University of Iowa

Date 1969	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
1 March	1957	2019	5	
	2139	2148	30	Maximum flux F(2-12 A°) = 0.11 erg $(cm^2\ sec)^{-1}$
2 March	0250	0256	5	
3 March	2217	2228	14	
5 March	0633	0635	5	Rapid rise, rapid decline
7 March	0209	0224	9	Complex rise
8 March	1802	1824	4-	Complex structure
9 March	0818	0854	10	Complex structure. Broad flat maximum 0833-0903 UT
	1016	1020	5	Rapid rise, rapid decline
	1205	1209	4-	Rapid rise, rapid decline
	1620	1625	4	Rapid rise, rapid decline
	1915	1922	8	
	2233	2237	5	
10 March	0759	0817	10	
	1925	< 1946	≥ 4	Peak not observed
11 March	0149	0159	4-	
12 March	1737	1745	115	Maximum flux F(2-12 A°) = 0.43 erg $(cm^2\ sec)^{-1}$
	2005	2011	7	
	2227	2231	4-	
13 March	2246	2258	6	
16 March	2109	2118	4	
	2334	2343	4	
18 March	0626	0636	11	
20 March	1630	1633	4-	
	2146	2152	4	
21 March	0133	0208	21	Note 1
	1320	1343	16	Note 1
22 March	0643	0647	6	Rapid rise, rapid decline
23 March	0627	0704	9	Slow rise, complex decline
25 March	0551	0606	4	Complex structure
26 March	0719	0725	5	
	0849	0925	5	
	1302	1311	4	
	1340	1412	4	Slow rise, slow decline
27 March	0048	0159	7	Slow rise
	1115	1119	4	
	1316	1337	37	Maximum flux F(2-12 A°) = 0.21 erg $(cm^2\ sec)^{-1}$
28 March	0056	0100	12	
29 March	1958	2002	8	
30 March	0246	0302	14	

Note 1: Homologous flares.

SOLAR X-RAY FLARES (2-12 A°)
SATELLITES EXPLORER 33 AND EXPLORER 35

APRIL 1969

University of Iowa

Date 1969	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 April	1829	1859	7	
3 April	1008	1014	4⁻	
	1300	1310	4	
4 April	0339	0346	4⁻	
8 April	< 0456	0510	4⁻	Onset not observed.
9 April	0342	0347	4	
10 April	0356	0404	15	
	< 1122	1209	5	Onset not observed. Notably long decline (~ 16 hrs).
13 April	1342	1354	4⁻	
14 April	0436	0458	4⁻	
	0556	0605	4⁻	
	0639	0701	4⁻	
	1106	1109	4	
	1710	1726	4⁻	
15 April	1352	1353	4⁻	
	2338	2442	4	Complex rise.
16 April	2033	2104	7	
18 April	0435	0445	4	
	0950	1001	6	
	1013	1019	8	
	2149	2158	4⁻	
19 April	0906	0912	5	
	1349	1357	5	
	1838	1847	5	
20 April	0928	0954	5	Complex rise. Also numerous small flares
21 April	0343	> 0348	> 4	Peak not observed.
	0829	0835	5	
	0909	0948	5	
	2004	2013	30	Maximum flux F_2(2-12 A°) = 0.11 erg $(cm^2\ sec)^{-1}$
23 April	0312	0333	5	Complex structure.
24 April	0309	0323	10	
26 April	> 2301	< 2316	> 7	Neither onset nor peak observed.
29 April	1042	1055	4⁻	
	1111	1118	4	
30 April	1429	1441	5	

SOLAR X-RAY FLARES (2-12 A°)
SATELLITES EXPLORER 33 AND EXPLORER 35

MAY 1969

University of Iowa

Date 1969	Onset UT	Maximum UT	Peak-Ratio to Quiet Sun	Remarks
2 May	1746	1758	18	Maximum flux F (2-12 A°) = 0.038 erg $(cm^2\ sec)^{-1}$. Complex decline.
3 May	1947	2006	4	
5 May	0859	1022	4	Slow rise, slow decline.
6 May	0236	0244	15	Maximum flux F (2-12 A°) = 0.033 erg $(cm^2\ sec)^{-1}$.
	0636	0648	7	
7 May	0156	0159	5	Rapid rise, rapid decline.
10 May	--	--	--	A notably quiet day.
12 May	0133	0143	4-	
	0526	~ 0615	~ 5	Peak not observed.
	0756	0811	5	
15 May	2217	2253	4	Complex rise.
17 May	--	--	--	Numerous small flares.
	1921	1929	12	Maximum flux F (2-12 A°) = 0.037 erg $(cm^2\ sec)^{-1}$. Complex decline.
18 May	--	< 0230	> 7	Onset and peak not observed.
	0545	0606	6	
	1447	1459	4-	
	1710	1723	18	Maximum flux F (2-12 A°) = 0.057 erg $(cm^2\ sec)^{-1}$.
	2059	2110	4	
19 May	0546	~ 0603	> 5	Peak not observed.
20 May	0034	0037	4	Rapid rise, rapid decline.
	1928	1943	4-	
21 May	0524	0535	4-	
22 May	0435	~ 0451	~ 4	Peak not observed.
	1859	1909	15	Maximum flux F (2-12 A°) = 0.041 erg $(cm^2\ sec)^{-1}$.
24 May	--	1052	5	Onset not observed.
25 May	1152	1219	4	Complex rise.
	2007	2025	4	Complex decline.
26 May	1100	1115	4	Complex structure.
27 May	0052	0057	7	
28 May	1254	1301	11	Maximum flux F (2-12 A°) = 0.027 erg $(cm^2\ sec)^{-1}$.
29 May	0019	0027	5	
	0405	0412	13	Maximum flux F (2-12 A°) = 0.048 erg $(cm^2\ sec)^{-1}$.
	1449	1500	7	
	1900	1918	4-	
	1938	1946	18	Maximum flux F (2-12 A°) = 0.042 erg $(cm^2\ sec)^{-1}$.
30 May	0609	0613	6	
31 May	1914	1946	8	Preceded by gradual rise beginning 1826.
	2103	2126	18	Maximum flux F (2-12 A°) = 0.036 erg $(cm^2\ sec)^{-1}$.

SOLAR X-RAY FLARES (2-12 A°)
SATELLITES EXPLORER 33 AND EXPLORER 35

JUNE 1969

University of Iowa

Date 1969	Onset U.T.	Maximum U.T.	Peak-Ratio to Quiet Sun	Remarks and Values of Maximum Flux F(2-12 A°)
3 June	0125	0133	4-	
	0414	0444	4	
	0713	0735	4	
4 June	0627	> 0638	> 4	Peak not observed.
	1647	1705	4-	
5 June	0954	1007	65	Apparent precursor began 0927. 0.28 erg $(cm^2\ sec)^{-1}$
	~ 1450	1512	17	0.072 erg $(cm^2\ sec)^{-1}$
6 June	0425	0443	4-	
	--	0609	4-	
	0629	0644	9	0.054 erg $(cm^2\ sec)^{-1}$
	0737	0745	4-	
	0815	0836	4-	
	1602	1609	10	0.049 erg $(cm^2\ sec)^{-1}$
	2352	2355	4-	
7 June	0018	0023	13	0.049 erg $(cm^2\ sec)^{-1}$
	--	1007	11	Onset not observed. 0.047 erg $(cm^2\ sec)^{-1}$
11 June	1616	1630	11	0.051 erg $(cm^2\ sec)^{-1}$
13 June	1545	1731	5	Slow rise, slow decline.
14 June	--	< 2204	> 5	Onset and peak not observed.
15 June	0345	0413	4-	
16 June	1253	1301	6	
	2020	2024	4	
	--	< 2113	> 12	Onset not observed.
18 June	1732	1736	4-	
23 June	0248	0256	7	
24 June	0043	0051	4-	

Note: During this period there is about 25% lost observing time in intervals of 0.5 to 2 hr. duration.

U. of Iowa 69-29
[Revised]

On the Electric Field in the Earth's Distant Magnetotail

by

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June 1969

[Revised 19 August 1969]

ABSTRACT

Solar electrons of energy $E_e \gtrsim 50$ keV are used as test particles for studying electric and magnetic fields in the distant magnetotail of the earth. During the prolonged solar electron event 10-22 November 1967 [Van Allen and Ness, 1969] simultaneous observations were made with the earth-orbiting satellite Explorer 33 in interplanetary space and with the moon-orbiting satellite Explorer 35 as the latter crossed the magnetotail. On the basis of the fact that the intensity of electrons was nearly identical at successive pairs of observational points during a wide range of geomagnetic conditions, it is inferred:

(a) that

$$\left| \int_{A'}^{B} \vec{E} \cdot \vec{ds} \right| \leq 1.5 \text{ kilovolts,}$$

where $\vec{E}$ is the vector electric field, from any cause, at a vector element $\vec{ds}$ of the trajectory of the particle and the line integral is taken along trajectories from source points A' outside the magnetosphere to a successsion of points B across the magnetotail at about 64 R_E (earth radii) downstream; and

(b) that, using (a), data from the above reference and observations of the very short delay time ($\pm$ 100 sec) in access of solar electrons into the central part of the magnetotail (impulsive event of 14 August 1968 as an example), solar electrons enter the magnetotail at downstream distances between 64 and 900 R_E [cf. Lin and Anderson, 1966].

Otherwise stated, it appears that the magnetic topology of the distant magnetotail is an "open one" (dynamic interconnection to the interplanetary field) and that there are no closed electrical equipotential surfaces beyond 64 R_E. This evidence supports the idea that the motional electromotive force that results from the movement of the interplanetary magnetic field with respect to the earth plays an essential role in magnetospheric physics, e.g., in driving magnetospheric convection, electrical currents in the polar ionosphere, etc.

U. of Iowa 69-36

Iowa Catalog of Solar X-Ray Flux (2-12 A°)

by

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July 1969

ABSTRACT

The absolute x-ray flux from the whole disc of the sun in the wave length range 2 to 12 A° has been observed for a prolonged period by University of Iowa equipment on the earth-orbiting satellite Explorer 33 and the moon-orbiting satellite Explorer 35, both of the Goddard Space Flight Center of the National Aeronautics and Space Administration. The observations are continuing at the date of writing (July 1969). A comprehensive catalog of the flux F(2-12 A°) is being produced. The observational technique and the scheme of reducing data are described herein. Sample tabulations and plots are given. A catalog of tabular and graphical data with a time resolution of either 81.8 or 163.6 sec has been completed for the following periods:

From Explorer 33: 2 July 1966 to 27 July 1967
From Explorer 35: 26 July 1967 to 18 September 1968

These blocks of data have been delivered to the

National Space Science Data Center
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771, U.S.A.

and made available through that agency to interested workers in

solar and ionospheric physics. Further blocks of data will be made available as they are completed. An abridged summary of principal flares is published in the monthly Solar-Geophysical Data of the U. S. Department of Commerce, Environmental Science Services Administration.

U. of Iowa 69-48

Energetic Particle Phenomena in the Earth's Magnetospheric Tail *

by

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*Paper given at Summer Advanced Study Institute/Earth's Particles and Fields 1969 at Santa Barbara, California, 4-15 August 1969.

ABSTRACT

Solar electrons of kinetic energy $E_e \geqslant 50$ keV are used as test particles to study the gross magnetic topology of the earth's distant magnetospheric tail and electric fields therein. The observations have been made with similar systems of detectors on the earth-orbiting Explorer 33 and the moon-orbiting Explorer 35. Based on study of electron shadowing by the moon, of the simultaneous intensity of solar electrons in interplanetary space and within the magnetotail, and of the very short time delay in access of impulsively-emitted solar electrons into the magnetotail, the following conclusions are proposed:

(a) The gross magnetic topology of the distant magnetotail is an "open" one (i.e., dynamic interconnection of geomagnetic field lines to those in the interplanetary medium).

(b) There are no closed electrical equipotential surfaces in the magnetotail at downstream distances greater than 64 earth radii.

(c) Solar electrons enter the magnetotail at downstream distances between 64 and 900 earth radii.

(d) Support is given to the idea that the motional electromotive force caused by the motion of the interplanetary magnetic field past the earth is responsible for driving magnetospheric plasma convection and electrical currents in the polar ionosphere.

The Correlation of X-Ray Radiation (2 - 12 Å) with Microwave Radiation (10.7 cm) from the Non-Flaring Sun*

by

Sister Jean Gibson, O.S.B.**

A thesis submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy
in the Department of Physics and Astronomy
in the Graduate College of
The University of Iowa

June 1969

Thesis supervisor: Professor James A. Van Allen

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**Part of the work was done while the author was a NASA trainee.

ABSTRACT

Absolute values of daily averages of the soft x-ray flux $F(2 - 12\ \text{Å})$ from the non-flaring sun are reported for 734 days during the period 1 July 1966 to 25 December 1968. The measurements were made with three thin-windowed Geiger-Mueller tubes on Explorer 33 and one on Explorer 35. The daily values were bounded between ≈ 0.4 and ≈ 6.8 milliergs/cm^2 sec during this entire period.

The daily values of solar radio power flux density P(2800 MHz) as reported by the Algonquin Radio Observatory, Ottawa are correlated with these daily x-ray values. As suggested by theory, the correlation is made between $\ln F$ and $1/P$. The correlation coefficient r is found to be 0.857 with 99% probability that the population correlation coefficient is in the range $0.831 \le P \le 0.881$. Assuming that there is scatter in both the x-ray flux and in the radio flux the least squares fit is

$$F = 27.3 \exp(-385.2/P)$$

where F is in milliergs/cm^2 sec and P is in flux units of 10^{-22} watts/m^2 Hz.

From a study of the theoretical relationships I make the following interpretation. The average temperature of the emitting regions is in the range $2.3 \leq T \leq 6.8$ million degrees and the average emission measure is in the range $7.6 \leq \int N_e^2 \, dV \leq 33.5 \times 10^{48}/cm^3$. The area of the radio emitting region is much greater than the area of the x-ray emitting region.

Soft Solar X-Ray Burst Characteristics*

by

Jerry F. Drake**

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Physics and Astronomy in the Graduate College of The University of Iowa

January 1970

Thesis supervisor: Professor James A. Van Allen

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**Part of the work was done while the author was a NASA trainee and part while a U. S. Steel Fellow.

ABSTRACT

The burst component of the solar x-ray flux in the soft wavelength range 2 Å < λ < 12 Å observed from Explorer 33 and Explorer 35 from July 1966 to September 1968 were analyzed. In this period 4028 burst peaks were observed.

The differential distributions of the temporal and intensity parameters of the bursts revealed no separation into more than one class of bursts. The most frequently observed value for rise time was 4 minutes and for decay time was 12 minutes. The distribution of the ratio of rise-to-decay time can be represented by an exponential with exponent -2.31 from a ratio of 0.3 to 2.7; the maximum in this distribution occurred at a ratio of 0.3. The values of the total observed flux, divided by the background flux, at burst maximum, can be represented by a power law with exponent -2.62 for ratios between 1.5 and 32. The distribution of peak burst fluxes can be represented by a power law with exponent -1.75 over the range 1 - 100 milli-erg $(cm^2\ sec)^{-1}$. The flux time integral values are given by a power law with exponent -1.44 over the range 1 - 50 erg cm^{-2}.

The distribution of peak burst flux as a function of Hα importance revealed a general trend for larger peak x-ray fluxes to occur

with both larger Hα flare areas and with brighter Hα flares. The heliographic longitude dependence of soft x-ray bursts indicated no significant dependence of x-ray burst occurrence on heliographic longitude; the emission thus lacks directivity.

The theory of free-free emission by a thermal electron distribution was applied to a quantitative explanation of both hard x-ray fluxes (data from Arnoldy, Kane, and Winckler [1968]; Kane and Winckler [1969]; and Hudson, Peterson, and Schwartz [1969]) and soft x-ray fluxes during solar x-ray bursts. Using bursts in three different energy intervals, covering a total range of 1 - 50 keV, temperatures of $12 - 39 \times 10^6$ °K and emission measures of 3.6×10^{47} to 2.1×10^{50} cm^{-3} were derived. The emission measure was found to vary from event to event. The peak time of hard x-ray events was found to occur an average of 3 minutes before the peak time of the corresponding soft x-ray bursts. Thus a changing emission measure during the event is also required. A free-free emission process with temperatures of $12 - 39 \times 10^6$ °K and with an emission measure in the range 3.6×10^{47} to 2.1×10^{50} cm^{-3} which varies both from event to event and within an individual event is required by the data examined.